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WM. SPRARAGEN
Editor

AMERICAN WELDING SOCIETY

EDITORIAL AND BUSINESS OFFICES

33 West 39th St.
New York, N. Y.

FALL MEETING

The fall meeting of the American Welding Society will be held in Boston during the week of September 21.

As in previous years the meeting will be arranged in conjunction with a welding exhibition held jointly with the American Society for Steel Treating. A number of other societies are planning to hold meetings in Boston during this week.

TECHNICAL PAPERS

The Meetings and Papers Committee are now at work on the fall meeting program and, also, on a list of suggested papers for local section meetings.

Every member of the Society who is willing to present a paper should notify headquarters of the availability of such material giving information as to the title of the paper and a sentence or two describing what the paper will be about. Preference as to section or national meeting for the presentation of such papers should also be stated.

The Meetings and Papers Committee also solicits papers for publication in the Journal of the Society regardless of whether they are presented before local sections or national meetings.

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A Hundred-and-One Cities Adopt Welding in Their Building Codes

With the recent adoption in Rochester of a new building code which includes permission to weld steel building frames in accordance with the American Welding Society's "Code for Fusion Welding and Gas Cutting in Building Construction," the total number of cities and towns which permet the use of welding has been brought to 101.

Weld Assurance

(Reprinted from March 26, 1931, issue of Engineering News-Record)

"How can I know a good weld?" is the first question that every prospective user of structural welding asks. And it is the question that every proponent of welding is bending his major effort to answer definitely and satisfactorily. Visual inspection, involving observation of the operator's technique, the arrangement and shape of the beads and the condition of the edges as well as removal of sections of doubtful welds to examine interior structure, has in general proved itself entirely adequate. In the final analysis, however, human judgment must be relied on, and absolute assurance of good welding is therefore still lacking. At the meeting of the American Society for Testing Materials in Pittsburgh last week some progress was made toward supplying this assurance. Thus, an inspection method using radium provides a photograph of the inside of a weld. Unlike the well known X-ray laboratory method, it may be used in the field, a small piece of radium and a sensitized film being the only equipment required. A test meter was also described which when slid across a weld indicates on a dial any subsurface imperfections. Iron powder sprinkled on a weld was shown to collect over porous spots or cracks. Our sense of hearing is also being utilized in weld inspection through the medium of the physician's stethoscope. Compared with visual inspection, these methods are positive. They are not infallible and they are perhaps a little expensive and troublesome, but they increase confidence in welding. And confidence—weld assurance—is the prime necessity of the moment.

German-English Welding Dictionary

The Verein Deutscher Ingenieure has recently issued a dictionary of welding terms to serve the welding engineer. It contains a large number of welding terms which are not ordinarily found in the usual technical dictionaries. Copies may be ordered from the VDI-Verlag G.M.B.H., Berlin NW 7, Germany.

Construction of Machinery

G. D. Spackman has been appointed chairman of the American Welding Society's Committee on the "Use of Welded Steel Parts for the Construction of Machinery."

Because of his extensive work with Lukens Steel Company in the development of welding quality rolled steel, and his thorough knowledge of welding engineering, Mr. Spackman was appointed president of Lukenweld, Inc., when that subsidiary was formed by Lukens Steel Company to manufacture machinery and equipment assemblies fabricated from rolled steel by arc welding.

Other members of the committee are:

J. L. Alden, The Western Electric Co.
G. O. Carter, The Linde Air Products Co.
J. H. Deppeler, Metal and Thermit Corp.
J. C. Lincoln, The Lincoln Electric Co.
E. L. Ragonnet, Air Reduction Sales Co.
J. G. Ritter, Westinghouse Electric & Manufacturing Co.
C. Schenck, Bethlehem Steel Co.

Report of Miller Memorial Medal Board of Trustees

The board of trustees have awarded the Samuel Wylie Miller Memorial Medal for the year 1930 to Eric Harold Ewertz.

Mr. Ewertz was a pioneer in the development and application of arc welding. Since 1912, when he first successfully demonstrated the practicability of arc welding, up to the present day, Mr. Ewertz has been an outstanding exponent of the welding art.

Born in Sweden, Mr. Ewertz came to this country at the age of 20 years, a graduate mechanical engineer. Prior to his coming Mr. Ewertz had worked in the foundry and machine shop of the navy yard in Sweden and also in the drafting and designing department of the Schwatzkoph Mashine Fabrik, Berlin, Germany.

Arriving in New York in the fall of 1893 he worked for a year and a half as driller and shipfitter at the Erie Basin Dry Dock Company, Brooklyn.

Later as draftsman on sugar machinery for Krajevsky and Phesant and on machinery for Gardner & Cox, yacht designers, New York, and for Roche's Shipyard, at Chester, Pa.

In the latter part of 1895, Mr. Ewertz became associated with the Crescent Shipyard, Elizabeth, N. J. Beginning as draftsman, he advanced rapidly to the position of chief constructor. Here he had charge of the construction of about 80 vessels, including the first successful submarine, the "Holland," and six others, also many types of naval and merchant vessels. Under his supervision the first pneumatic tools were tested out; the first smokeless powder machinery and testing guns were built; experiments with the one-man torpedo were carried out, as well as the field guns for firing dynamite charges.

In 1903, Mr. Ewertz resigned to accept a position as general manager of the Victor Metals Company, Weymouth, Mass. Here he specialized in high-strength bronze and copper-nickeled alloy castings.

In 1905 he took charge as assistant manager of the construction of submarines at the Fore River Shipbuilding Company, Quincy, Mass. This company later being absorbed by the Bethlehem Shipbuilding Corporation. There he built some 80 submarines for the United States Navy, Spain, Russia and Chile.

Under his supervision the first organized mass production of war vessels was undertaken; and in 1914 completed a contract with the British Government for 20 submarines in 15 months.

Back in 1912, Mr. Ewertz became interested in electric arc welding and succeeded in his experiments at Fore River to demonstrate the practicability of arc welding.

He was the first man to successfully utilize electric arc welding in marine construction. Following his pioneering work, Mr. Ewertz became "welded minded" and extended the use of arc welding in ship construction as fast as the development or proper equipment permitted. This new tool was of great service in hastening the construction work during the late war.

In October, 1917, contract was signed with the United States Government for the building of a new 15-million-dollar plant and the construction of 35 destroyers; all to be delivered in 27 months. Taking charge of this undertaking proved to be a most interesting opportunity for service to his country.

Four months after breaking ground, ship construction was started and advanced as the plant grew. Seven thousand men were engaged in building the plant, and the number of ship workers was gradually increased to about 9000, all in accordance with carefully developed procedure, permitted a mass production of ships and corresponding low cost. In 1918, with 13 months of the contract time spent, 65 per cent of the contract was finished.

After the war, in December, 1918,

Mr. Ewertz took charge as general manager of the Moore Plant of the Bethlehem Shipbuilding Corporation, Elizabeth, N. J. Here, in addition to ship construction, Mr. Ewertz produced machinery for oil refineries, ship deck machinery, all types of pumps, steam turbines, Diesel engines, oil burning equipment and general machine and foundry work.

In 1928, Mr. Ewertz resigned to establish his consulting welding engineering practice in New York City in order to further promote and properly develop the vast possibilities of fusion welding in ship construction, steel structures, storage tanks, and to render assistance in redesigning and surveying.

In 1918, Mr. Ewertz was appointed as member of the Emergency Fleet Corporation Welding Committee, and was also in charge of all welding development for the Bethlehem Shipbuilding Corporation.

Elected Member American Welding Society in 1921.

Served as chairman of New York Section of American Welding Society 1922-24.

Wrote paper on "Welding in Ship Construction" published by the Society in Marine Engineering and in booklet form.

Elected president of the American Welding Society for term 1924-25.

Since then served as director and member of its executive committee.

Chairman of its Educational Committee.

Chairman of Joint Unfired Pressure Vessel Committee organized by the American Society of Mechanical Engineers and American Welding Society.

Member of the Executive Committee of the American Bureau of Welding.

Member of the Society of Naval Architects and Marine Engineers.

Associate Member of the Naval Engineers Society.

Chairman Board of Trustees, Epworth M. E. Church.

President, Young Men's Christian Association, Elizabeth, N. J.

Member Board of Governors of St. Elizabeth Hospital.

Member and past vice-president of Elizabeth Chamber of Commerce.

Member and former director of New York Board of Trade.

SECTION ACTIVITIES

CHICAGO

The following new officers of the Chicago Section were elected:

Chairman—H. C. BOARDMAN, Chicago Bridge & Iron Works.
Vice-Chairman—C. C. WHITTIER, Robt. W. Hunt Co.

CLEVELAND

At the April meeting of the Cleveland Section the following nominations were made:

Chairman—E. R. BENEDICT, United District Heating, Inc.
First Vice-Chairman—A. E. ABBOTT, The Linde Air Products Co.
Second Vice-Chairman—S. P. FETTER, Air Reduction Sales Co.
Secretary-Treasurer—E. T. SCOTT, Cleveland School of Welding, Inc.

NEW YORK

The New York Section reports the following officers elected:

Chairman—H. M. PRIEST, American Bridge Co.
First Vice-Chairman—J. B. TINNON, Metal & Thermit Corp.
Second Vice-Chairman—H. H. MOSS, Linde Air Products Co.
Secretary-Treasurer—A. F. KEOGH, Sound Welding Co.
Executive Committee—Messrs. C. Kandel, J. W. Owens, G. N. Bull and F. E. Rogers.
Representative on National Board of Directors—P. W. Swain.
Executive Committee for One Year to replace Mr. H. H. Moss—Mr. T. C. Fetherston.

An inspection trip by the Section was held on Saturday, May 23. About 300 people attended in spite of bad weather. The party assembled at the Brooklyn Navy Yard and were given an opportunity of seeing the laying out of shapes and their fabrication for the steel structure of the ship. Arc welding is being used to large extent in the fabrication of the light cruiser New Orleans in order to save weight. Practically all fittings are welded, as well as the forward part of the ship, including the strength hull. The length of the cruiser is 588 ft., the breadth 61 ft. 9 in., draft 21 ft. 7 in. and displacement 10,000 tons.

Passing through the assembly field there was exhibited a number of test specimens of welded and riveted construction. Two welded pontoons were also shown, and an all-welded seaplane wrecking derrick now nearing completion. There are over 17,000 ft. of welding on this vessel.

The party then walked around the main and second decks of the U. S. S. Pensacola. Extensive welding operations were used on non-strength portions of the hull to save weight.

The entire trip proved to be very interesting and instructive. All those who attended were highly pleased.

PITTSBURGH

The 1930-31 activities of the Pittsburgh Section of the American Welding Society were brought to a close on May 25, when a meeting was held in the Carnegie Lecture Hall on the subject of Structural Welding. Prof. J. Hammond Smith, head of the department of civil engineering, University of Pittsburgh, read a paper on "Strains and Rigidity of Fillet Welds." The data contained in Professor Smith's paper was obtained while conducting experiments on structural joints for the Structural Steel Welding Committee of the American Bureau of Welding and from data obtained by senior engineering students preparing graduating theses on this subject. The plotted curves presented by Professor Smith show that the stress on a fillet weld is greater at the ends than at the middle. This end stress can be made to become greater at either end by varying the thickness of the grip and connecting plates of the joints. The data also proved that the welded connection is more rigid than a rivet connection, all conditions being equal.

A. R. Ellis, vice-president of the Pittsburgh Testing Laboratory, discussed the inspection of an 18-story welded steel building erected in Lynchburg, Va. Mr. Ellis told why it is just as important to properly inspect a welded structure as it is to obtain a proper design of the joints to be welded. Over 13,000 lineal feet of welding was used in this building, of which approximately 240 feet of welding had been rejected. His company has adopted the stethoscopic method of examining welded joints. Approximately 315 tons of shop and field welded steel was used in this building. The steel was all encased in concrete.

The following officers were reelected for the 1931-32 season: Chairman, L. R. Gurley, editor *Welding;* vice-chairman, E. L. Quinn, supervisor welding and cutting, Jones & Laughlin Steel Corporation, and secretary and treasurer, Joseph F. Minnotte, secretary-treasurer, Minnotte Brothers Company, all of Pittsburgh, Pa.

SAN FRANCISCO

The May meeting of the San Francisco Section was held on the 22nd. Joseph Shaw, development engineer for the Bechtel-Kaiser Company, presented some very interesting figures on the new 24-inch high-pressure gas line recently constructed from Amarillo, Tex., to Chicago; and discussed the problems that were met and overcome during the construction. Hugh Brown, of Brown Brothers Welding Company, who were one of the subcontractors on the line construction, also explained to those present some of the unique feats performed in meeting the problems that arose on this job.

EMPLOYMENT SERVICE BULLETIN

SERVICES AVAILABLE

A-132. Structural Engineer, experienced designer, estimator and salesman of structural steel and ornamental iron, both riveted and welded.

A-133. Welder or welder supervisor. Have had eleven years' experience with arc and acetylene welding. Am capable of laying out and setting up welding jobs and have had charge of welding on several construction jobs. Have had experience in handling men. Also experience in high pressure and high temperature oil refinery and steam power work, including shop and field installations. Have had experience in welding stainless steel. Since February, 1928, have been connected with the M. W. Kellogg Company. Can furnish reference from this company and others.

Arc Welding of Ventilating Equipment

By **W. L. PROUT**

✦ Mr. Prout is connected with the Sales Department of the American Blower Corporation, Detroit.

WE are doing some considerable welding at our factory as is indicated by some of the photographs attached. Fig. 1 shows an ABC special pressure blower as constructed at the present time. The old style had a cast iron sub-base which is now being replaced with a welded steel sub-base made up of structural members and plates.

Fig. 1—Special Welded Pressure Blower

Fans which require these sub-bases are always designed and built to fit the particular job on which they are to be used and the same sub-base could never be used on any two jobs. This, of course, means that whenever we make a cast iron sub-base, we have to make up a pattern which must be destroyed when the job is completed as it is of no further use. The steel sub-base eliminates this pattern charge in addition to any other saving inherent in this type of construction.

The cast iron supporting members and angle stiffeners riveted to the housing have been replaced by strip steel welded to the housing. The machining of the castings is eliminated and, of course, the steel construction is considerably lighter in weight for equivalent strength.

The old bolted scroll angle joints have been replaced by continuously welded seams. These fans are designed to develop pressures as high as 45-in. water gage, which corresponds to 26 oz. per square inch. This is about the highest practical limit for single stage centrifugal fans. Naturally under such

Fig. 2—High-Speed Forced Draft Fan

a pressure the joints must be very tight. Scroll angle construction, whether riveted or bolted, requires careful fitting and the use of gaskets on all joints. With the welded joints, it is a comparatively simple matter to obain a permanently tight seam.

On the new types of welded fan the upper section of the housing can be lifted off and the wheel and shaft lifted out. This is much simpler to do in the field as it is sometimes difficult to remove the shaft from the wheel while the wheel was still in the housing, which was necessary with the old type of housing. Of course we made split housings before welding became so popular, but we find that the use of welded strips on these joints simplifies the operation considerably. It is easier to bolt the two joint strips together and then weld to the housing and get a good tight joint than it was when we used angle iron riveted to the housing.

Fig. 2 shows the housing of a 1930 type of high speed forced draft fan.

Note the welded scroll joints and the steel stiffeners welded to the housing, replacing the old construc-

Fig. 3—Old Type Sintering Fan

tion where riveted and bolted scroll angles and stiffening members were used. A sintering fan constructed in 1914 and one constructed in 1930 are shown in Figs. 3 and 4, respectively. The gases handled by these fans contain considerable abrasive material and fans must be constructed to resist this abrasion and permit the renewal of worn parts. The housing and inlet chute of the 1930 fan are constructed entirely of 3/8-in. steel with continuously welded seams except on those joints which must be taken apart for the renewal of parts. The scroll in this case is made in sections with the scroll angles welded to it and bolted to the side sheets, and renewable scroll liners are bolted to the scroll sheet proper. Renewable side liners are also provided—bolted to the side sheets.

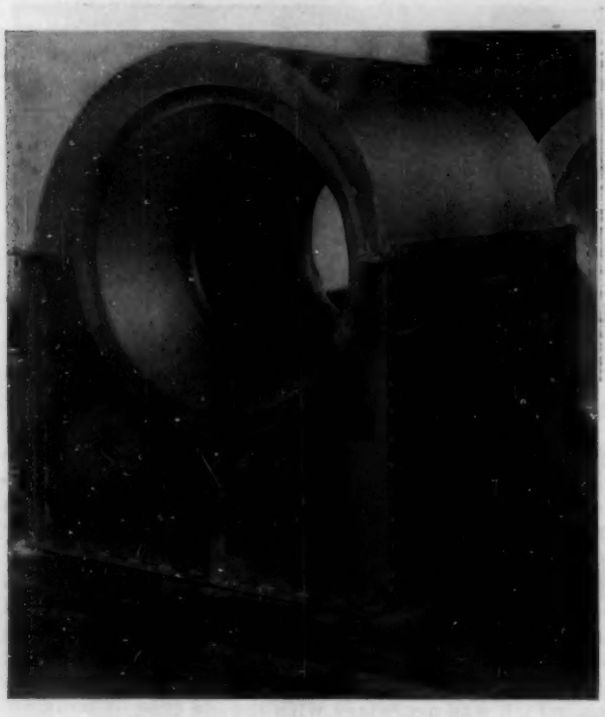


Fig. 4—A Modern Welded Sintering Fan

The illustrations above are applications in industrial and mechanical draft fields which require heavy gages of steel.

We are unable to show a saving through the use of arc welding except where the required duty calls for heavy gages. Just where the dividing line is depends upon any number of conditions, such as the size of the sheets used. On our average run of jobs we find it better to use riveted construction on less than 10 gage. Where 3/16-in. steel or heavier is called for welded construction is preferred.

We use arc welding almost exclusively for the sort of work shown in photographs submitted and practically all our joints are butt joints. We do not find it necessary to chamfer the sheets.

We do considerable spot welding where lighter gages are encountered. Our series 30 Sirocco and HS fans, which are used for ventilating purposes, have the scroll angles spot welded to side sheets and the angle stiffening members also spot welded to side sheets. This saves some labor, is at least as strong as the riveting formerly used, and is neater in appearance.

Maintenance Welding in Steel Plants

By E. L. QUINN

✦ This paper was presented at the October 22nd, 1930 meeting of the A. W. S. Pittsburgh Section, by E. L. Quinn, Supervisor Welding and Cutting, Jones & Laughlin Steel Corporation, South Side Works, Pittsburgh, Pa.

OXY-ACETYLENE welding and other methods of welding are becoming more important in the maintenance work in steel mills. Some of you may be directly connected with this maintenance problem, but many are not and for those it might be well to explain that there are many different types of steel mills. Even in different mills turning out the same finished product, the processes may vary to such an extent that the maintenance problems may also be different.

As a general rule, the different applications which will be cited will apply at any mill. However, due to variations as pointed out, different methods of attack for a particular job may be better suited and in extreme cases, even different methods of welding may apply.

Maintenance is one of the most important phases in any industrial plant. Welding, as stated before, is becoming one of the most important factors in maintenance work. How to "Control Welding" is, therefore, the "moot" question. This is especially true when some of the other factors in maintenance are considered:

In many instances time is an important factor; in many others quality of material is unknown due to stresses or fatigue caused by operating conditions. In a majority of cases the finished job can not be tested except when actually placed in service.

To illustrate the position welding has attained, it has become general practice to consider welding before making any decision regarding scrapping a piece of equipment. Of course, the decision as to welding or scrapping is always based on economic study or in special cases, when equipment can not be delivered and serious shutdown might otherwise occur.

In maintenance work three processes most generally used are: Thermit, Electric Arc and Oxy-Acetylene.

"A" Qualification of Operators

One of the first factors in controlling welding is that of securing good operators and maintaining good welding practices after they have been obtained. These two conditions naturally come into two groups: 1st, New Men, and 2nd, Old Men.

The new men are interviewed to determine their experience, to judge their character and examined to determine their physical condition, including their eyesight.

If the men pass the interview successfully, they assume the rating of a "Probationist."

The "Probationist" welder is given instructions on the safety regulations in force and is equipped with necessary safety appliances.

Without additional instruction, he is given a welding job on pipe usually 8 in., 5/16-in. wall thickness, care being taken not to let the welder know that he is making a test weld, but on the contrary to attempt as far as possible to make him believe he is doing actual production work. From the weld on pipe, coupons are cut out and weld specimens tested for ductility, and ultimate strength. The fractures in the weld are examined for penetration, grain structure and other factors.

Providing a man passes these qualifications, he advances to the second part of the probation period. In this period the operator welds on different jobs brought into the welding shop. A very close observation can and is kept on the work of the operator including his preparation, his welding technique and the appearance of the finished job. There are so many diversified jobs that in from a week to ten days it is possible to determine the operator's ability as well as his limitations.

The maintaining of quality work is somewhat more difficult. From time to time the operator's welds are tested in conjunction with tests made in determining quality of welding rod, which will be discussed a little later. From the operator's standpoint two or more operators are requested to make test pieces with a sample rod. Here results should be reasonably the same and if not, investigation made to determine whether the operator is at fault.

The practice of having a distinguishing mark for each welder and require him to mark all work for record purposes is believed to have a tendency to maintain and perhaps improve the quality of welding, and in the extreme cases of failure definitely establishes the responsibility for any improper welding that might be done.

Selection of Welding Rod

Many authorities on welding have discussed to a greater or less extent factors involving or rather determining the quality of a weld. This leads to the point as to what constitutes a "good weld." It is my opinion that one of the most important factors in "Control Welding" is the selection of proper rod. To best illustrate this one can take the best welder in the country, give him hay wire with the request to weld the very best quality of high carbon steel, and regardless of his proficiency, he can not make a good weld. I do not agree with those who believe that a rod can be and should be used for general all around welding. On the contrary, I firmly believe that every particular job, involving a particular material requires a definite welding rod to obtain the best results, and it is these results for which we all are striving.

In view of the above, welding rods have been tested for the past eight years to determine as far as possible the best uses for each particular rod. To illustrate this point, an occasion developed in the past two weeks to test three different types of bronze rod. For purposes of discussion the rods will be called A, B and C. The results of the tests indicated that rod "A" and "B" developed nearly the same strength and from a tensile strength viewpoint, either of them could be used. With bronze rods, another characteristic had to be determined, namely, hardness, and in this case rod "B" gave a harder surface, and therefore would be better adapted for uses involving wear or abrasion. It developed that rod "C" was lower in tensile strength and had approximately the same hardness as rod "A." It was, therefore, concluded that rod "C" could be disregarded, use rod "A" where strength and ductility are required and rod "B" where strength and hardness are desired.

The same procedure is followed in the case of steel rod. In selecting a rod for a particular welding job, the service to which the equipment is subjected and the analysis of material must be considered if best results are to be obtained.

Another feature presents itself when welding dissimilar metals, especially alloys to carbon steels. Here it is necessary to find the proper rod. A manufacturer of a particular alloy may send welding rod of this particular alloy, but when used with carbon steel, good results may or may not be obtained. This recalls to mind that recently a heat resisting bar was welded to a carbon steel bar (0.35 carbon), with the alloy manufacturer's rod, obtaining very poor results. After considerable experimenting it was found that best and most satisfactory results were obtained using two different types of alloy rods, one containing manganese and silicon and the other nickel. This illustration points out an extreme case of obtaining the proper welding rod for a particular job. (It is hoped that no one will ask the question whether it would not be preferable to have the material all in one rod. It would, but the amount of work involved does not warrant requesting that this be made up.)

Selection of Method of Repair

The qualification of operators and the selection of rod may be considered as general requirements for all work. The method of welding to be selected for a particular job, of course, depends upon the character of the job, the service which equipment is subjected to, as well as other factors. It is, therefore, not general but a specific problem. It is assumed that all present are familiar with the different methods of welding. It will, therefore, be sufficient to state that in maintenance welding there are only three methods generally employed—Thermit, Electric and Oxy-Acetylene.

Perhaps the best manner to explain what method to employ will be to use illustrations of specific jobs, which have been carried out and explain why a different method was used on each particular job.

In discussing the illustrations, it appears logical to include other data or information, such as design of joint; material used, cost of welding; elimination or reduction in time of shutdowns as well as savings tangible or otherwise.

Thermit Welding

The use of thermit welding is confined principally to heavier sections and where relatively large amounts of weld material are required. There is usually very little trouble in deciding where thermit welding should be employed. However, like every other rule, there are usually exceptions.

The reclamation of rolls presents itself as the predominating application where thermit welding is employed. During the past five or six years the thermit process has been used on more than 100 jobs. These included, in addition to above, roll housings, engine bases, shears, pinion teeth, etc. The maximum amount of thermit poured at one heat was 2000 lb., with the average of approximately 600 lb. per weld. The cost

of thermit welding is usually based on pounds of weld metal. It has been found that a figure of $0.60 per pound of thermit poured is fairly accurate. This naturally brings up the question of how to determine the amount of thermit. For standard shapes, the chart prepared by the thermit company has been found to be exceptionally accurate. For irregular sections it is believed that the best practice is to use one bag of thermit for each pound of pattern wax applied. A bag of thermit weighs approximately 29 lb. and will produce about 16¾ lb. of steel on reaction.

One of the most interesting problems involving thermit welding was a manipulator rack. This rack is used to transfer ingots or blooms from one pass to another. It is approximately 24 ft. long with a cross section comparable to that of two 15-in. I-beams placed flange to flange. The break occurred through the entire section approximately 5 ft. from one end. This piece of equipment was such that it was not thought necessary to carry a spare. It was in service about one year when it failed. Operation of mill without rack reduced production over 30 per cent. It was welded and back in service within two (2) days. The spare ordered for this work, even though it was rushed, required two weeks for delivery. The welding can, therefore, be credited with 30 per cent production for at least ten days, which in dollars and cents is a considerable amount of money.

The actual cost of welding was about one-fifth of the cost of new manipulator rack, and effected a material saving.

Electric Welding

Electric welding in maintenance work is one of the most important processes. There is an existing opinion that it is limited to steel welding. In its present development it does not appear that the best results can be obtained on cast iron work. Even with studding it is only a patching job.

Limiting electric welding to steel work does not, however, decrease its importance in maintenance work. There are many applications where electric welding is best suited. Welding of steel castings, structural welding, tanks and stacks are some of the general fields.

Castings are being replaced rapidly by the use of rolled steel shapes and plates. This method of construction has many advantages over castings and offers a large field for electric welding.

The welding of narrow gage locomotive frames is an interesting application. These frames are 4 in. x 3 in. The savings incurred by welding these frames is approximately 90 per cent of the cost of dismantling and installing a new frame. During the past seven years approximately thirty fractured frames have been welded, thus effecting a handsome saving.

The method of welding which is believed most suited for locomotive frames is the electric arc. There may be some who have repaired frames by both thermit and oxy-acetylene. If it were not for the design of the locomotives in many instances of this kind, the thermit or oxy-acetylene may be considered. However, the electric method is preferred, as the boilers on narrow gage locomotives are very close to the frames and electric welding:

1st—Eliminates necessity of dismantling and reassembling.
2nd—Eliminates consideration of preheating as it is not essential.
3rd—Reduces the heat to which operator may be subjected.
4th—Allows better control of alignment.
5th—Reduces the problem of residual or welding strains or stresses.

The repairing of boilers is another interesting application. Due to variations in repairs, it is somewhat difficult to give figures on cost of welding, savings or other factors. It is the most excellent example of intangible advantages or savings of maintenance welding.

The electric welding process is used on boiler work and the reason for this method is no doubt clear to all.

1st—The regulations as set forth by the A.S.M.E. Boiler Code permit electric welding within certain limits.

2nd—Insertion of patches by electric welding reduces the problem of expansion and contraction, which in turn influences the strains set up. These strains are called by different names, principally welding or residual strain or stresses.

3rd—In many cases patches are close to riveted seams and electric welding does not tend to loosen rivets as the heat does not extend as far as with acetylene welding.

As to the design of joint used, fillet welds predominate. However, where one or more sides are free, the butt weld is used and preferred. The increased use of welding in repairs on boilers and the confidence that is being placed in welding where properly supervised, influences me to state that I believe the time is not so far distant when boilers will be entirely welded, especially on types used on locomotives. The welded boiler would eliminate many of the repairs now being made.

From time to time the welding department is called upon to do work which may or may not fall into the classification of maintenance. As an illustration of this, electric welded stacks 90 ft. high, 4 ft. in diameter of 3/16-in. material have been built.

The welding of these stacks has the advantage of securing better draft conditions by tightness. It removes seams or rather lap joints which are ideal places for corrosion to start. These stacks were welded and erected at a material saving over riveted stacks.

In welding these stacks the sections are spaced 1/16 of an inch apart and tack welded both longitudinal and girth seams before actual welding takes place in which case the girth seams are welded first. The type of joint used may be considered as a double Vee. As the plate is only 3/16 in. thick no bevel is used but the material is welded from both sides.

The stacks are fabricated in two parts of 45 ft. each, delivered to the boilers where the two sections are joined by a girth weld and erected as a unit.

The completed product makes a very fine appearance and as required all riveted stacks will eventually be replaced by welding. Alignment was maintained within ¾ of an inch, and considering the length as well as the plate thickness, believe that is working to pretty close tolerances.

There is one other type of electric welding covering the field of surface hardening alloys. This will be covered later in discussing oxy-acetylene welding and the advantages of each method pointed out.

Oxy-Acetylene Welding

The third method of welding in maintenance work is the oxy-acetylene or gas welding. With the nature of its heating, practically any type of repair can be made with this method. Of course, as pointed out,

the other methods of welding may be more desirable due to various conditions, and therefore should logically be used.

The oxy-acetylene methods of welding naturally divides itself into different and distinct classes of work:

1st—Steel welding.
2nd—Cast iron.
3rd—Non-ferrous metals.
4th—Surface hardening alloys.

Steel Welding

The maintenance work on steel was discussed in detail under electric welding. Due to this it will not be necessary to go into detail on this work, but merely point out to applications where oxy-acetylene appears to be the best. In the repair of forgings the selection of rods, when gas welding, is such that better results can be obtained. Due to rod and also technique, a good operator can more closely approximate the grain structure than with any other method.

The other application is that of pipe welding. On new installations and in replacement of pipe, oxy-acetylene welding is extensively used. The sizes that have been welded run from 2 to 20 in. in diameter. The service to which pipes are subjected are:

1st—Air pressure of 90 to 100 lb. per sq. in.
2nd—Steam pressure of 150 lb. per sq. in.
3rd—Hydraulic pressure of 550 lb. per sq. in.

The maintenance on lines welded is practically nothing. While no records are available as to the savings, it can be stated that in a number of cases special fittings were constructed which not only saved expense on cost of original fitting, but either reduced the loss in production rate or the length of a mill shutdown.

Cast Iron Welding

The development of what is now known as bronze welding makes it necessary to divide the welding of cast iron into two classes:

1st—Cast iron welding.
2nd—Bronze welding of cast iron.

As a general rule, the second method is becoming more general in use. However, considerable welding with cast iron filler rod on miscellaneous castings is done. The reason for using cast iron in place of bronze on this work being that of alignment. In place of chipping or grinding in preparation for bronze, the pieces are placed in position and cast iron melted out and then welded, first from one side and then the other. It has been found by this technique that the dimensions and alignment could be held to closer tolerances.

From time to time there is also larger work where cast iron welding is preferred. Such a case is illustrated in bumpers on narrow gage locomotives. When a locomotive is being repaired, it is possible to remove the bumper, preheat and build up the worn surface of the cast iron. As it was desirable to have a better wear resistant surface on the bumpers, experiments developed an abrasive resistant alloy puddled with the cast iron surface which reduced the wear about 70 per cent.

Another illustration of cast iron welding is that of welding chilled surface rolls. A particular roll was that of a plate mill, the roll being 24 in. in diameter with a 12-in. diameter neck. Due to the chilled surface, thermit welding could not be used. Electric welding, in my opinion, is not suitable for cast iron work. Bronze welding of this roll when consideration is given to heat in service, does not appear to be practical. The only method left, therefore, was cast iron welding.

A double vee was burned out after local heating and welded. In order to keep the heat very low and maintain the chilled surface, the work was done very slowly.

This particular job was not a question of saving between welding and a new roll, but falls into that intangible classification of maintaining and keeping the mill in operation. The roll was welded and returned to service in a remarkably short time. This roll remained in service until repeated dressings made it unfit for further use.

The bronze welding of cast iron has many advantages over cast iron welding. Many times it eliminates preheating of equipment, lower temperatures are used; the casting does not become so hot or in other words, less heat is required. In addition to the above, greater strength can be obtained and the weld withstands sudden shocking to a much greater degree.

One of the most exacting as well as difficult bronze welding jobs was in welding a cylinder on a large vertical engine. This cylinder was 52 in. in diameter with a 48-in. stroke and 1-in. wall thickness.

It is believed that a connecting rod first broke and this allowed the piston to drive up against the head of cylinder with sufficient force to break the wall around the entire cylinder just below the flange. Many difficulties had to be met successfully to insure a good welding job, as follows:

1st. Alignment must be very close if methods as employed on smaller castings and cast iron were resorted to and considerable heat would be involved.

2nd. There were no facilities available for preheating such a large piece of equipment in a manner satisfactory for cast iron welding. However, sufficient preheat could be obtained to speed up the welding with bronze and relieve all welding strains.

3rd. The type of rod selected was a bronze which would give the known highest tensile strength. Experiments had been previously made which indicated that one could depend upon 54,000 lb. per square inch for the ultimate strength when properly welded.

The casting was first prepared with a vee and then aligned. In welding, two men worked at opposite sides and varied their position to control the alignment which was checked every 20 to 30 minutes. The inside was welded first and then the outside. Upon completion, alignment had been maintained to within 1/16 of an inch and upon cooling, this did not change appreciably.

Four hundred pounds of bronze was used on the job and the welding, including all charges, cost only about 1/12 of the price of a new cylinder and is still in service after more than three years' operation. As the engine was used in power work, no claim could be made for keeping mill running as the power could have been purchased. This particular job, however, was oustanding and demonstrated that welding with proper control, could be depended upon for strength and that with reasonable care, equipment could be welded and held to close tolerances of alignment.

The welding of non-ferrous metals, such as aluminum, copper brasses and bronzes, is readily accomplished with oxy-acetylene welding. Care must be exercised in welding of different materials. The property of material being welded, the service to which it

will be subjected should be known so that an intelligent selection of rod can be made.

An outstanding illustration of welding non-ferrous metals is the practice of building up worn bull rings. These rings are constructed of bronze. They are approximately 50 in. in diameter with a 10-in. face and 3 in. thick. The fact that analysis may influence the length of service of a piece of equipment is forcibly brought out with this ring. Rings of different basic analysis were used with a variation in service of from 6 months to 18 months with a corresponding increase in initial cost for the rings giving the longer service. It has been very gratifying to find that even with what might be considered as the poorer quality, when built up with bronze rod, the same length of service was obtained as with the better class of new material. It showed that the proper rod was being used.

Although the cost of welding the bull rings is high due to the large amount of bronze required and the length of time for welding, an appreciable saving was effected over the cost of a new bull ring of poorer quality with a corresponding higher saving over rings made of better quality material.

Surface Hardening Alloys

There are so many different kinds of surface hardening alloys on the market and claims for each, that time would not permit to go into detail on this class of work. However, it is becoming of such importance that it may be well to point out briefly the high spots involved.

Gas welding will, if desired, give a somewhat harder surface due to the carbonizing action of the acetylene flame that can be employed, and also due to the fact that when electric welding the alloy is contaminated with base metal to a considerably greater extent than with oxy-acetylene.

In most all cases, especially of heavier sections, it has been found that heating for both methods give better results in that there are less welding strains and better alignment can be obtained.

The character of the alloy, of course, is the most important factor. To make the proper selection, one must know whether the abrasive action is all that must be considered or whether heat in addition is involved.

As a general rule the electric welding process is used on forging work. On castings, however, in my mind, there is no choice, as with oxy-acetylene, impurities, sand inclusions, etc., can and are removed so that a better quality of surfacing can be obtained. There is a tendency if electric welding (which by the way is always used for this work with reversed polarity) is used on castings, to have a porous condition in addition to somewhat lower resistance to abrasion.

Welding, both on production as well as maintenance work, has advanced to a large extent. Welding is becoming more generally known and recognized. More literature is being published and manufacturers are continually carrying on research work to develop new applications, rods, etc.

However, with all the progress there is much to be desired. There are still objectives to be reached and for these objectives we all should strive along the following lines:

1st. Work with the metallurgical department, if you have one. Interest them in helping you determine best rod to use, the analysis of material and the quality of weld obtained. By having their cooperation, much is accomplished, they become welding-minded, they know the advantages as well as limitations, they realize that with proper control, welding can be depended upon.

This department has contact with practically every other department and if you can make the personnel of this department welding-minded, they will help considerably in selling "welding."

2nd. When failures occur and welding is considered as the method of repair, do not be satisfied to just weld the fracture. Study the failure to determine its origin. Analyze the failure to determine whether welding will have a fair chance or whether its location and design is such that it may be subject to failure regardless of the quality of weld made. In other words, do not take a chance on a failure unless such chance is pointed out.

By constant application of the principles above enumerated, the value of welding will become more impressive and attract additional attention to the end that welding processes will be used for a constantly increasing number and kinds of application. We in the welding industry, especially the members of the American Welding Society, have been of service in promoting welding. Progress has been phenomenal and will, I am sure, continue.

Before closing I might add just a thought which appears to be appropriate and that is to arouse the interest of all having any contact with welding to attend the meetings of the American Welding Society and, if possible, influence them to become members.

Stronger Windshield Frames

By **J. P. WATERS**

✦ Mr. Waters is connected with the Linde Air Products Co.

AN automobile body company which had been using the oxy-acetylene process in a number of production operations for some time recently extended the use of this process to another product. In connection with the manufacture of windshields, it was the desire of this plant to produce a stronger windshield frame and at the same time one which would possess such desirable qualities as lightness and a neat appearance. Since welding had been employed with such excellent results in the assembly of various other automobile parts, it was realized that this was the ideal method to use for fabrication of these frames.

The windshield frames were accordingly re-designed to take advantage of the possibilities afforded by welded construction. The sheet metal department was reorganized and enlarged to provide the proper facilities for this added production schedule.

The frames were fabricated from ⅛ x 1-in. T-iron and all the joints were made by oxy-acetylene welding. Carefully designed jigs were employed to maintain the frame in perfect alignment for welding. There was no question that the use of welding resulted in the production of a much stronger and finer frame.

Regulations for Structural Welding in Germany*

By DIPL.-ING. OTTO BONDY

STRUCTURAL welding is a development of the past five years. While it is true that welded steel structures were erected in Germany some years previously to test their load capacity, the first application of arc welding to the construction of shops and other buildings was in America in 1926. Welding has now been introduced in nearly all industrial countries where steel is produced and consumed. Progress in this field has depended on the enthusiasm and devotion of a small number of specialists.

Construction of welded steel buildings in Germany has come to the fore rapidly since early in 1929. A number of shop buildings, trestles and welded structural members[1] have been fabricated by welding. The German State Railroad has fallen in line with this modern trend by erecting a welded bridge 10 meters (33 ft.) in length on one of its main lines.

Some months ago a steel roof truss of a shop with a length of 20 meters (66 ft.) was welded at Siemensstadt, near Berlin. The girders, entirely welded from plates, have a span of 10 meters. For the German State Railroad in Stettin the roofs of a platform, with one column, have been completely welded. At Riesa (in the center of Germany) large dust-coal bunkers with trestle-work were erected by arc welding. The structure has a weight of 95 tons; a saving in weight of about 20 per cent was effected through the use of welding.

A wide-span framework for a roof truss was welded at Niederschöneweide, near Berlin, to cover a shop of the German State Railroad. At Dortmund girders erected for a welded shop have a web depth of 3 meters (9 ft. 10 in.). For a new structure at the Deutsches Museum in Munich cantilevers of I-form were welded together, because there was no room for riveting or screwing. This list could be greatly extended.

The rapidly growing vogue of welded steel structures in Germany created a demand for legal regulations for their design and calculation. At the beginning of 1930 a draft of rules for erecting welded steel structures was published[2]. It was prepared by Prof. Dr.-Ing. Hilpert of the Technical University of Berlin in conjunction with Mr. Cajar and the writer. The Fachausschuss für Schweisstechnik (Special Committee for Welding Technique) of the Verein Deutscher Ingenieure paved the way for collaboration of the specialists with the government authorities and the structural steel industry.

Shortly afterward regulations were promulgated by the Prussian Ministry of Public Safety. These were based partly upon the original draft of rules, but in many respects are more extensive. Particularly noteworthy is the paragraph on the calculation and the permissible stresses. The table gives permissible unit stresses for both Germany and the United States.

Permissible Unit Stresses in Pounds per Square Inch

		Tension	Compression	Bending	Shear
Germany	Base Stresses	10,300	12,800	as for	8,600
	Stresses Increased by ⅓	13,800	17,200	and	11,500
United States		13,000	15,000	compression	11,300

The comparison in the table shows that the base stresses stipulated by the German regulations are much lower than those of the American regulations. But it may be said that the German regulations refer to open-hearth steel (St. 37), the rupture-load of which is about 37 to 45 kg. to the sq. mm. (53,000 to 64,200 lb. per sq. in.). It may also be mentioned that the German regulations provide an increase over these base stresses by one-sixth to one-third, provided certain conditions regarding the design and execution are fulfilled. The stresses increased in this manner are approximately the same as those in America, exceeding them by a trifle.

The technical and economical advantages of welding are steadily becoming better appreciated by the German structural steel industry. The experience of the next few years will decide to what extent the application of welding in the construction of buildings and bridges will replace riveting.

Regulations prescribed by the Prussian Minister of Public Safety, Berlin, constitute the remainder of this article.

Rules for Erection of Welded Steel Buildings in Germany

For welded steel buildings generally the regulations regarding the loads accepted for buildings, dated Dec. 24, 1919, are in force (so far as they are still valid), as well as the regulations regarding the permissible stresses and the calculation of structures made of open-hearth steel, etc., dated Feb. 25, 1925, so far as not conflicting with the following provisions.

Erection of welded steel buildings assumes, to a special degree, thorough knowledge and practical experience in this method of building. Therefore only trustworthy contractors should be entrusted with the erection. The prescribed inspection and supervision of the construction must be by an engineer experienced in welding, and he must have assistants skilled in this work.

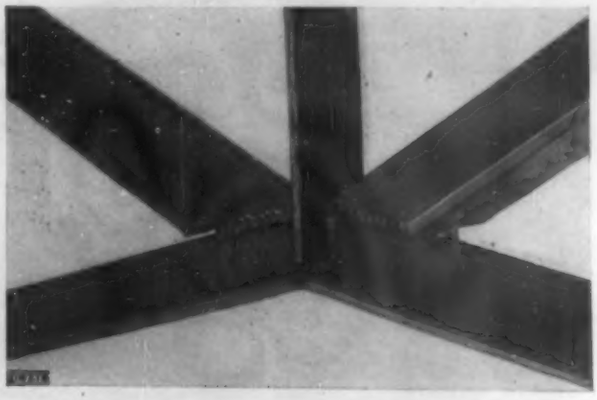


Fig. 1—Welded Joint in a Roof Truss of 11.9 m. (39 Ft.) Span

*Cuts loaned through courtesy of *Iron Age*.

[1] One hundred pictures and drawings of welded steel structures are assembled in: Bondy "Ausgewählte Schweisskonstruktionen, Stahlbau," Vd I-Verlag, Berlin, 1930.

[2] "Die Elektroschweissung," Berlin, January, 1930.

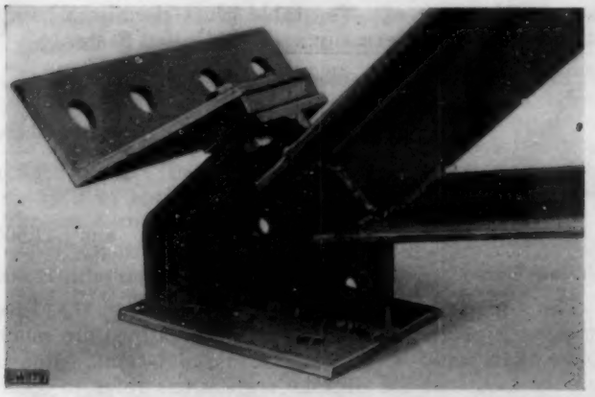


Fig. 2—End Joint in the Same Roof Truss Represented in Fig. 1

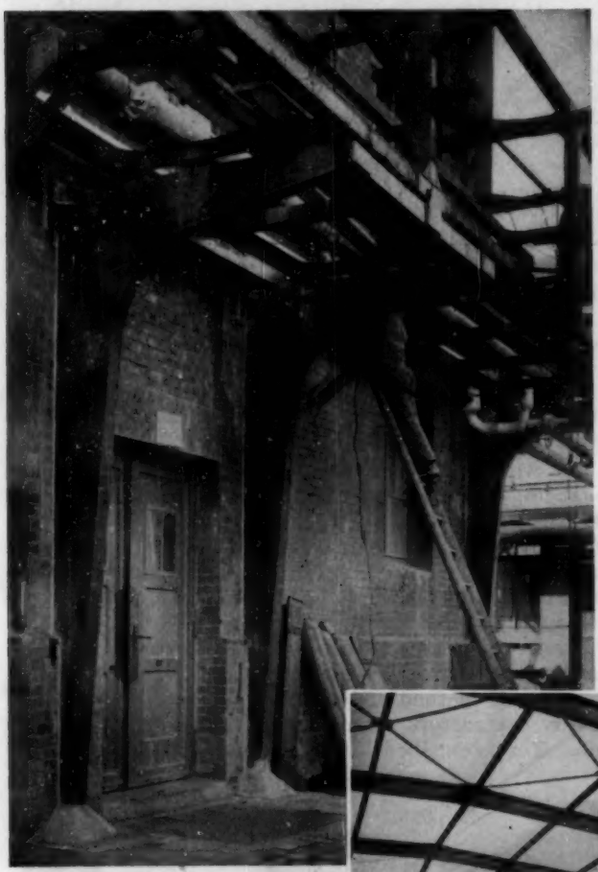


Fig. 4—(Above) Welded Supports for a Pipe Line Bridge in a Gas Works Near Leipzig

All materials which fulfill the above specifications are admitted, so far as their qualification for welding is evident, in addition to those materials which are certified for this method of building by reason of tests.

Welding wires are to be chosen according to the different locations (horizontal, vertical, overhead) in such a manner that they might be welded satisfactorily.

Methods may include arc welding (d.c. or a.c.), resistance welding or gas welding. The choice of the welding method and of the equipment is left in the hands of the contractor, but must be made in such manner that unfavorable accessories during the welding are avoided.

Erection Requirements

The location of welded seams to be made in the field must be marked in the shop. Also the order in which the seams are welded during erection must be generally fixed beforehand, by the responsible supervisor of the erecting firm or by his representative, in such manner that no dangerous stresses remain. Regulations for welding in the field stipulate the following:

Tack welds for assembling are to be made without forcing together the individual parts. Clamps or screw-vises may be used only to avoid movement of the parts during the welding. Surfaces to be welded must be free from rust, dirt, etc.

When welding has to be done in the field, which is to be limited so far as possible, suitable accommodations must be provided, such as protection of the welder from the weather, etc., to guarantee satisfactory welding.

For the static calculation, the design and the execution the same principles are valid as for riveted structures, unless the special character of the method of building demands new ideas in construction. At the joints, for example, there are to be placed, if necessary, beads, etc., as a protection from water; these beads cannot be considered in connection with transmission of stress.

In the specifications and drawings the selected method of welding and the kind of welding wires are to be stipulated. The welded joints must be arranged so that they are easy to inspect and to survey. In the draw-

Fig. 3—(At Right) Welded Steel Structure in the Siemens-Schuckert Works in Berlin. This Building, Erected in 1930, Measures 10 x 20 m. (33 x 66 Ft.), and is 6.3 m. High (20 Ft. 8 In.)

ings the welded seams are to be marked in the same way as stated in the static calculation.

Welded joints which are exposed to tension or compression are to be calculated by the relation:

$$P = F \times p$$

whereby $F = a \times l$

In this formula

P = the load in kg. to be transmitted by the welded seam,

F = the section of rupture of the welded seam in sq. cm,,

a = the throat of the welded seam (cm.); for fillet welds, the height of the isosceles triangle marked within the cross-section of the fillet weld, not one of the two longer sides (Fig. 12); for butt welds, the thickness of the cross-sections to be connected; when they differ, the thinner prevails (Fig. 13),

l = length of the welded seam, exclusive of the length of the two craters at the ends, with the length of 2 a for each.

Those parts of the structure which are exposed to bending moments can be assembled by interrupted seams sufficient to take care of shear stresses due to bending.

By using structural steel "St. 37" the permissible unit stresses (p) follow.

Fig. 5—Welded Frame at Right and Welded Bridge Construction at Left, Designed for Use in a Railroad Station Near Berlin

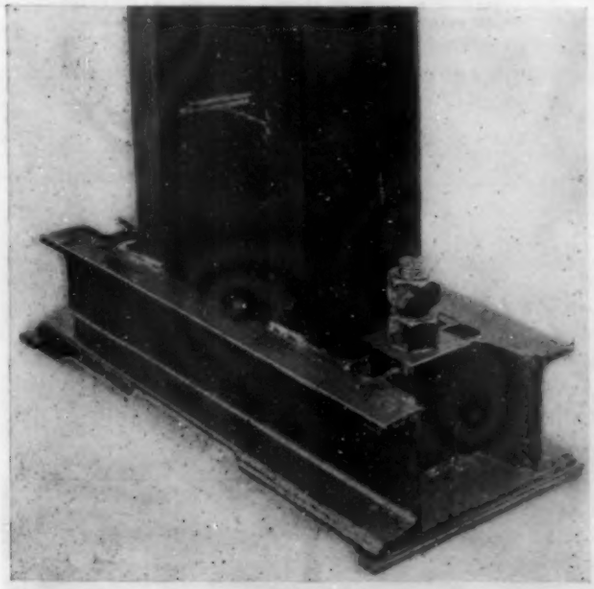


Fig. 6—Foot of a Column of a Crane Runway. The Two Channels of the Column are Stiffened by Welded Sections of I-Beams Between Them. All Parts are Welded Except the Anchor Bolts

Fig. 7—Inside of a Built-Up Girder of an Arc-Welded Railroad Bridge 8.86 m. Long (29 Ft. 1 In.)

Fig. 8—(At Left) Highway Bridge at Leipzig. The Girders are Made of I-Beams Reinforced on Each Flange by Three Superposed Plates Attached by Arc Welding

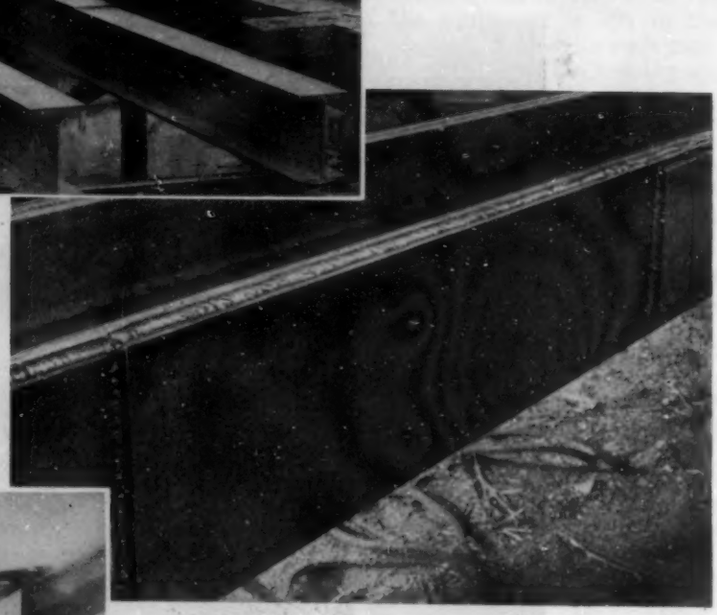


Fig. 9—(At Right) Detail of One of the Girders of the Bridge in Fig. 8. This Shows the Way the Reinforcing Plates Were Welded to the I-Beam

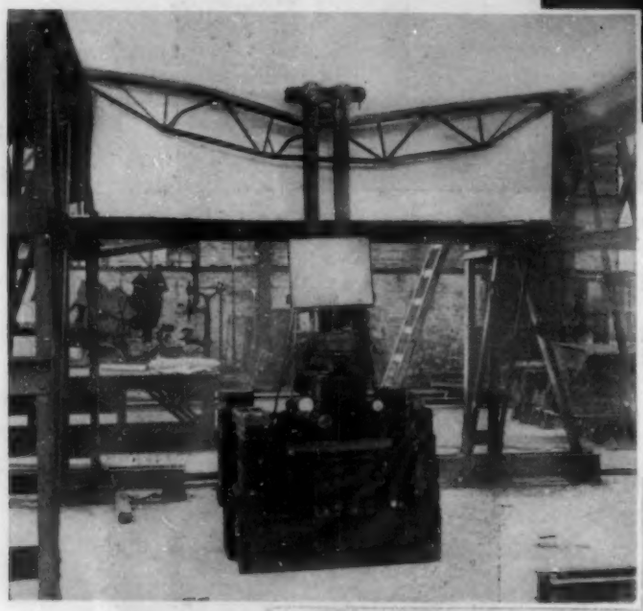
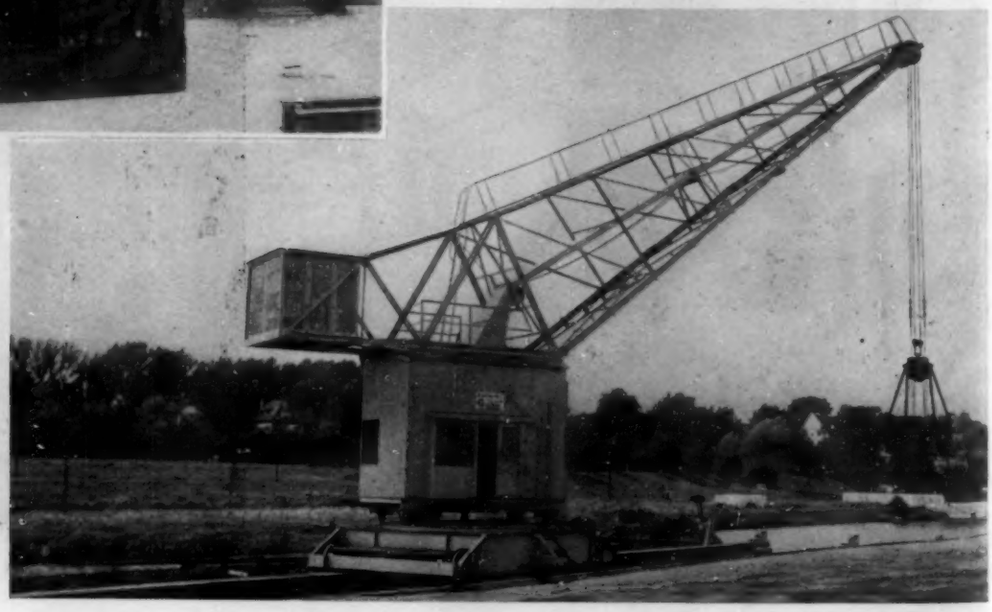


Fig. 10—(At Left) Model of an Arc-Welded Crane Structure Tested to Destruction. This Shows the Buckling of the Members Through Imposition of a Load of More Than 5 Metric Tons

Fig. 11—Harbor Crane of 6 Tons Capacity, All Parts of Which Were Welded; This Includes the Rolling Framework and the Crane Arm With Its Counterweight



Tension, 720 kg. to the sq. cm. (about 10,300 lb. per sq. in.)
Compression, 900 kg. to the sq. cm. (about 12,800 lb. per sq. in.)
Bending, as for tension and compression
Shear, 600 kg. to the sq. cm. (about 8600 lb. per sq. in.)

Under combined loading by longitudinal stresses and shearing, the total unit stresses must not exceed the maximum stresses given. For those parts of the structure which are exposed to alternating or dynamic stresses, for cranes of all kinds as well as for all seams welded overhead, the stated permissible stresses are to be reduced by one-sixth.

Generally, the specified stresses may be raised under the same conditions as they are fixed by the aforesaid official regulations regarding the permissible stresses, etc., of steel structures, dated Feb. 25, 1925.

Inspection and Contractor's Test

Examination of the welders shall prove their ability. It shall be made with the same welding wire and, so far as possible, with the same kind of machinery or tools which the contractor uses in the shop and in the field. The following examination is necessary:

Fillet welds are to be made on two longitudinal sheets exactly vertical, one above the other, upon a horizontal piece (Fig. 14), making a cross in transverse section. The welded seams are to be laid under a right angle to the direction of the lamination. The height of the welded cross is 300 mm. (11.8 in.) plus thickness *s* of the sheet.

The thickness *a* of the seam prescribed to the welder has to be 0.6 times the thickness *s* of the sheet. The two longitudinal sheets which are to be welded upon the horizontal sheet are to be about 20 mm. (0.8 in.) shorter than the cross sheet, so that tack welds can be placed at the heads. The beginning and the end of the welded seam will not be considered when cutting out strips for test. Two of the four fillet welds (1 and 2) are to be welded in a horizontal direction, the sheets

Fig. 12

Fig. 13

being in vertical and horizontal position; the other two (3 and 4) in a vertical direction.

Out of the welded sheet three strips each about 35 mm. (1.4 in.) wide are to be cut by cold saw and pulled in a machine in direction of line *W-W*. In this case the rupture load applied to the unit of the cross-section *F* must produce at least 30 kg. to the sq. mm. (43,000 lb. per sq in.). Otherwise the welder is to be rejected.

When any welding overhead is to occur, it may be required that two seams of the test piece be welded overhead.

Test of the Welding

In using the same kind of welding and the same welding wires as for the erection of the structure the following tests are required: Test of a transversal fillet weld according to Fig. 12; test of a longitudinal fillet weld.

Four strips corresponding to the thickness of the parts in the construction are welded together in horizontal or vertical direction to a test piece by longitudinal fillet welds (Fig. 15). The length of the seams has to correspond nearly with the width of the straps. In this case the cross-section where the rupture occurs has to

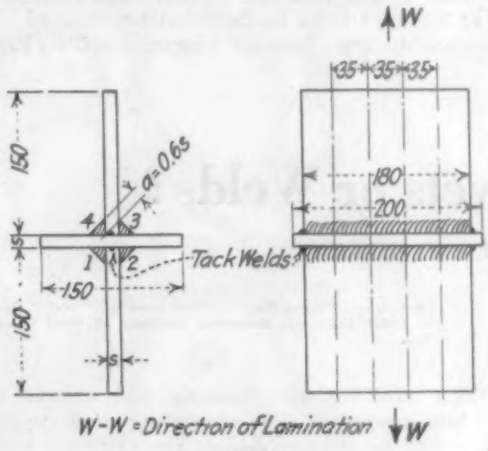
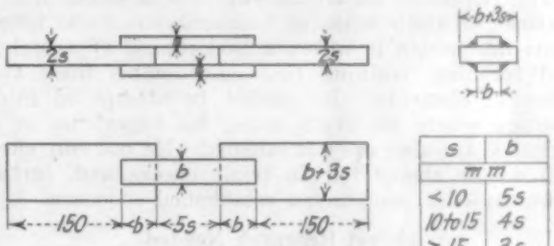


Fig. 14

produce a rupture load by shearing of at least 24 kg. to the sq. mm. (34,400 lb. per sq. in.).

Two sheets, each 6 or 12 mm. (¼ or ½ in.) thick, corresponding to the thickness of the parts being joined, are welded together to a test piece by V- or X-seams (Fig. 16). The beveled borders of the seam shall form an angle of at least 60 deg.



s	b
mm	mm
<10	5s
10 to 15	4s
>15	3s

Fig. 15

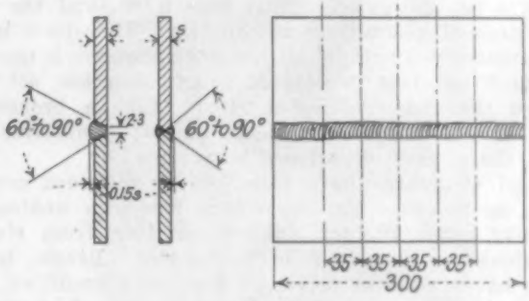


Fig. 16

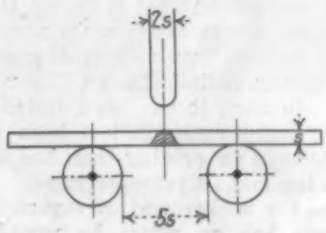


Fig. 17

The test pieces may be subject to a test for tension or bending. In tension the rupture load must attain at least 30 kg. to the sq. mm. (43,000 lb. per sq. in.).

In special cases a test for bending may take place. For plates up to a thickness of 20 mm. (0.8 in.) a rod of twice the thickness of the plate with a circumferential radius of the thickness of the plate is to be put exactly on the middle of the seam; at V-seams this has to be done at the root-side of the seam; the welding seam at the root is to be flattened beforehand.

The clear distance between bearings is 5 *s* (Fig. 17).

The experiments shall be generally limited to plates of 6 and 12 mm. (¼ and ½ in.) thickness. The test piece is to withstand bending through at least 60 deg. before the first rupture occurs.

For the test which has to take place chiefly in the shop under the supervision of the local building police, all welds must be easy of access. Welded parts, so far as they are not yet tested, are to be covered, before leaving the shop, with a transparent paint only. Field welds are also to be tested and in special cases loading tests may be required by the inspectors.

Rivets or Welds?

By **LEE H. MILLER**

✦ Extracted from May 7, 1931 issue of "Steel." Mr. Miller is Chief Engineer, American Institute of Steel Construction Inc.

BOTH riveting and welding will always constitute processes for connecting steel parts and it will be the problem of the engineer or architect to keep himself so informed that he can tell his clients with confidence where and how either rivets or welds can be used. Based upon present experience and information the writer considers it folly to claim we are now ready to abandon rivets since welds can be made to replace them, and it is as great a folly to wipe welds from our industrial processes because we lack the experience to inspect and analyze their properties.

The competent structural engineer is gifted with an instinct or sixth sense of balanced structural proportions into which is woven a background of experience and technical training that co-ordinates these three essential elements. He cannot be stampeded into a position where his sixth sense, his experience or his technical training are not satisfied. He not only checks and double checks but he triple checks and, furthermore, he does each in an established sequence.

Rivet Research Needed

Rivets have been his companions and almost his bedfellows for the years of his experience, and the experiences of generations before him. They have been so constantly a part of all his work that much needed research on their process of functioning has not received the consideration merited. Like a broken-in shoe they almost automatically adjust themselves to meet the stresses occasioned by service.

Steel structures have failed under different conditions as to cause but the writer has been unable to identify any structural failure resulting from rivets or where rivets have failed in service. Rivets, however, have failed in driving, either as a result of excessive heating in rivet manufacture or in driving.

It must be recognized that with all the years experience and use, rivets are not foolproof. Furthermore, research has not been as extensive and data have not been as widely distributed as the rivet's importance merits. In fact, it has been stated that in the last five years more research has been pursued and more data published on welding than has been the case with rivets in the last 50 years or more.

With as broad a background of experience on welds as the engineer has on rivets he would find many places where economy and safety are satisfied by welding. It is simple with satisfactory existing methods to assume a "show me" attitude toward welds, believing that when the other fellow has developed his experience it can be acquired and put on with no more delay than changing a pair of shoes. This unfortunately is not true. There are many places of secondary nature, however, where welds can be used and experience acquired without involving the primary parts of the structure.

Opportunity for Welding

In the case of steel plate floors, for instance, which do not involve the main frame, opportunity is afforded to use many times the amount of welding that the main frame would require. The problems of welding a structural frame differ from those involved in welding smaller units where by careful research it is possible to establish procedure and sequence for exactly duplicated conditions, and produce satisfactory results. In a structural frame the various connections are not duplicated and are related to each other in a manner that as yet is difficult to control.

Electric arc welding involves conditions resembling foundry castings, except that the liquid metal is in much smaller units and is not poured from a ladle. It differs from the chilled casting of the foundry in that the electric arc by its action heats part of the parent metal. It permits the inexperienced or careless welder to produce a result in the metallurgical structure similar to that occurring in burned or overheated rivets. It involves cooling strains and shrinkage similar to foundry work where the patternmaker must use a special scale of measurements amounting to approximately 3/16 inch per foot.

Welders Take Rigid Tests

An examination of these conditions does not mean they cannot be met successfully just as they have been in foundry work, and it is possible that welders will attain a closer approximation to perfection than founders and in fewer years of research.

In connection with the large welded skeleton frame office building in Dallas, Tex., more than 100 supposedly competent welders tried to qualify for this work. Of this number, 22 were subjected to qualifying test, and only 10 were accepted for shop work, and half of these, or 5, for field work. This appears to be a high mortality rate, but perhaps if as rigid test were applied to riveters many would also fail. The company constructing this building acquired valuable experience under the supervision of consulting engineers representing the owners and they give assurance that under similar conditions they would be glad to do similar construction, but they have no intention of scrapping their riveting equipment.

Welding has made possible the manufacture of equip-

ment that has been of great economic value to industries. Large pressure vessels 8 feet or more in diameter carrying pressures of more than 1000 pounds per square inch at temperatures over 1000 deg. Fahr. have been welded of steel plates from 4 to 6 inches thick. Axial seams and dished heads have been butt welded by depositing layer upon layer of arc weld metal to build up the full strength of the heavy walls of the vessels. The wall thickness of many of these vessels is beyond that in which riveting has ever been undertaken. It has been found that a single deposited line forming a fillet bead has a coarse uneven structure but as the succeeding layers are deposited there is constantly increased refinement of the metal previously deposited. This condition is particularly conspicuous in the texture of the fracture which shows the various stages in refinement of the built-up metal.

Relation of the Engineer

The relation of the engineer to rivets and welds is that of designing, inspecting and reporting to the purchaser whether the work is in accord with the conditions of the purchaser's contract. The relation of the manufacture of single unit articles is that of designing, workmanship, inspection and guaranteeing the purchaser that all is done in accordance to a specification acceptable to the purchaser.

The relation of a manufacturer or fabricator of a structure is that of providing material and workmanship in accordance with an engineering specification, and to the satisfaction of an engineer of inspection representing the purchaser. It is apparent that engineers and inspectors are going to prefer the type of connection that they best understand, and feel most competent to report to the purchaser regarding workmanship.

The routine of rivet inspection has a background of procedure that has met industrial and technical requirements over a long period of time and the nondestructive test or inspection of welds is relatively little understood. Until this talent is more widely distributed the conservative engineer adheres to rivets, but he can contribute to the distribution of knowledge on welds by employing them for secondary parts of the structure where the functions of the main frame are not involved.

The relation of the building official to rivets and welds is quite different from the others mentioned in that he must administer enacted public safety ordinances and participate or recommend the revisions of such ordinances to meet advancing conditions, but always remembering that he must administer the revisions. He must deal with the talented and the ignorant since both are his public. To whatever extent he varies from the written code he becomes personally involved.

Aim Is To Protect Public

It is not the function of the building commissioner to guarantee an individual that his building is constructed in accordance with a purchase contract, but it is his function to protect the public against individuals constructing buildings in violation of enacted safety codes. The commissioner is naturally opposed to codes that are impossible or difficult to enforce with the inspection forces under his direction. He hesitates to approve what the engineering profession has failed to recognize and is competent to design, supervise and inspect.

It is the opinion of the author that welds should be permitted for secondary parts of structures which do not involve the primary stresses of the skeleton frame and for primary stresses for the present when the owner assumes the responsibility for proper design, material and workmanship. To advance the welding art and insure safety such primary welded construction should be designed and supervised by a competent committee approved by the commissioner and the records of their experiences and recommendations should become available to the commissioner and the engineering profession.

Better Chutes

By **A. G. WIKOFF**

✦ Mr. Wikoff is connected with the Linde Air Products Co.

USERS of chutes and similar conveying equipment can realize the savings effected by welding in this section of the plant as well as in others. An important advantage of welded chutes, of course, is the smoothness of the seams which prevent any clogging due to projections or roughness on the chute surface.

Lumber companies particularly realize this advantage since jams in conveyor equipment may mean serious delay. A typical example is found in the plant of a western lumber company which uses welded steel chutes to full advantage. These chutes are used to regulate the hog feed as it goes into the boiler fire-boxes. They are 4 x 14 x 48 in. in size, made of 12 gage steel, all welded, Fig. 1. Not only do these regulate the hog feed but with the trap doors closed and filled up with hog feed they seal the fire-boxes from air, an advantage when the boiler-room crew is off duty.

An unusual application of oxy-welding to chutes was observed recently at an ore company plant. This company used wooden chutes which required replacement very often. An oxy-acetylene service operator suggested that they place strips of 2 x 2-in. angle iron cut with the oxy-acetylene blowpipe into 12-in. lengths across the bottom of the chute, about 8 in. apart. As

the ore comes down the chute it fills up the spaces first, lining the bottom so that a stationary layer of ore protects the chute from the abrasive action of the moving ore.

Welding Inspection

By R. KRAUS

✦ This paper was presented at a symposium on welding under the auspices of the Pittsburgh Section of the A. W. S. and the Regional Meeting of the A. S. T. M., March 18, 1931. Mr. R. Kraus is Supervisor of Welding Inspection, Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa.

THE question, "can the quality of a finished weld be determined from its external appearance," is frequently asked by those who become interested in the application of welding. An answer in the affirmative can be given. A good and a bad weld have their definite characteristics, easily recognized by average inspectors and supervisors, no elaborate methods or rules being necessary.

INSPECTION IN PROCESS

A weld is intended to be a suitable bond between two component parts of a structure. To accomplish that purpose, fusion of the weld with the parent material is necessary. To make sure of it is the most important function of the welding inspector. He has to follow the technique of the operators by watching the welding in process through a hand shield at intervals. He must be certain of sufficient penetration and fusion along both sides of the fillet as well as at the root of it. The same applies to the sides of butt welds or any space intended for a weld.

Methods of Weaving

Various ways of guiding the electrodes along the intended path of the weld are in practice, requiring different degrees of skill. The inspector is satisfied with any of them so long as the common purpose is met, namely, fusion. The technique of semi-circular motion, shown in Fig. 1 (*b*), is well known. The operator must stop for an appreciable moment at each end of the stroke in order to assure penetration. This weave is not adaptable for a single bead fillet. Another method, shown in Fig. 1 (*a*), is a triangular path, which lends itself particularly to getting fusion in the corner and on the sides. The operator must also hesitate for a moment at each corner of the triangle. This triangular path is well adapted for vertical welds, in which case, for good fusion, a slow motion along the sides with a pause at the corners is followed by a faster one along the hypotenuse to prevent the hot metal from rolling over, Fig. 1 (*c*). For proper results with the semi-circular path as well as with the triangular motion, it is absolutely essential that the operator stops at each end of the stroke. If he does not, and changes the first method to the sweeping motion of a paint brush and cuts corners for the second, modifying the triangle to an oval (Fig. 1 (*d*)), poor fusion will result. In order to be sure of good fusion, by an operator of medium skill, our company adopted a method of laying beads parallel with the length of the weld, followed with cover beads for ⅜-in. fillets and larger. The beads are laid with practically no weaving, consequently, the operator does not have the problem to remember to hesitate for penetration. With the cover bead, the operator works again almost mechanically; he turns along the fillet at an angle, turns the corner at the fillet edge and, thereby, obtains positive penetration. Figure 2 illustrates the method for ¼, ⅜, ½, ¾ and 1-in. fillets. The path of the cover bead is indicated separately.

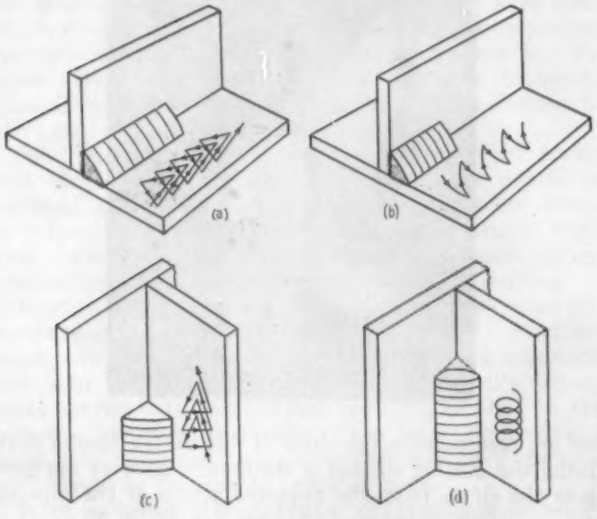


Fig. 1—Correct and Incorrect Methods of Weaving
(a) Triangular path. (b) Semi-circular motion.
(c) Triangular path for vertical welds. (d) Oval motion.

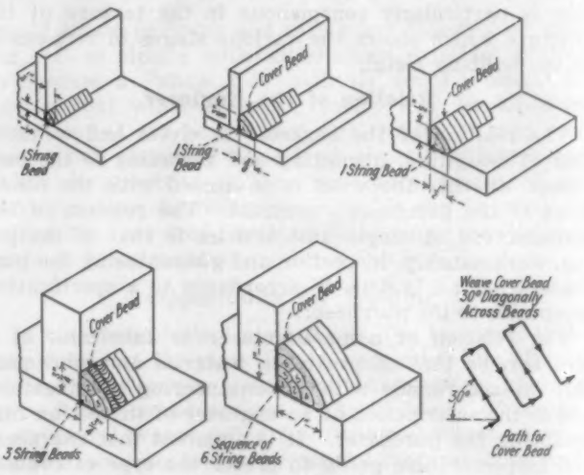


Fig. 2—Welding Methods

Length of Arc and Position of Electrode

The inspector must see that a short arc is maintained consistently by the welders. The length of the arc should about equal the diameter of the rod used. A short arc prevents the absorption of oxygen and nitrogen by the hot metal, the absorption of oxygen creating oxides, and the absorption of nitrogen causing brittleness of the iron. Another essential feature of the short arc is better penetration, because of the small surface heated. With a long arc, too large an area is covered by the unsteady arc to secure penetration.

The operator, also, has to hold the electrode correctly, namely, vertical to the pool and not at an incorrect angle. In extremely bad cases, the operator may even hold it parallel with the pool, just melting the rod and running the hot metal ahead of him without penetrating into the parent material.

In the language of the shop, it is correct to pull the weld, but not to push it. Fig. 3 shows the two methods.

When pieces of different thickness are being welded together, it is necessary that the arc is played sufficiently on the heavier section; otherwise, fusion will be missing there; the greater thermal capacity delays

the material from reaching the fusion temperature. Fig. 4 illustrates the method for materials of different thickness; also of welding sheet steel to heavy angles; and, for comparison, the position of the electrode is also shown for plates of the same thickness.

An indication of penetration is frequently evident along the edges of the fillet as a slight undercut. In a vertical weld it is visible in both walls enclosing the fillet, in a horizontal weld only in the vertical sidewall.

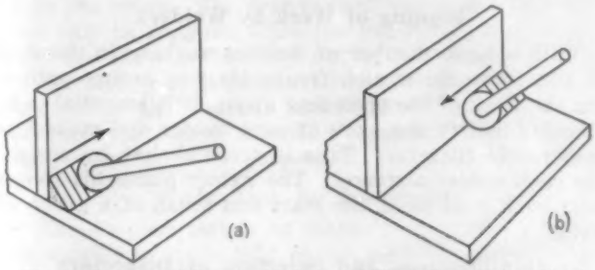


Fig. 3—Correct and Incorrect Relation of Electrode to Molten Metal
(a) Correct method. Rod vertical with face of pool.
(b) Incorrect method. Rod parallel with face of pool.

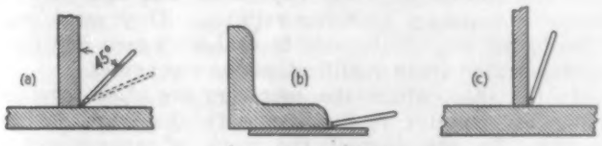


Fig. 4—Correct Angle of Welding Rod
(a) Position of electrode for material of approximately the same thickness. The incorrect position is shown dotted.
(b) Welding a ⅛-in. sheet-steel plate to a heavy angle.
(c) Position of electrode for materials of unequal thickness.

At the horizontal leg of the fillet the undercut cannot be seen, because under influence of gravity the molten material fills completely the cavity created by the arc. The slight undercut referred to should appear like a shadow line only. A deep undercut in both walls indicates that an excessive current has been used for the size of the electrode. Lack of fusion will show up in extremely bad cases as soon as the material cools. The contraction of the weld metal will cause the base of the filler to pull away from its seat on the parent metal to which it was not fused. This condition is more likely to occur in corners which are subject to magnetic blow. The defect can be noticed by the accumulation of iron particles along a clearly defined line due to the magnetism created in the steel during the welding. If the evidence is obliterated by brushing or shot blasting, it can be easily reconstructed by blowing iron dust against the suspected area. The same method can be applied to make sure of a crack. The two sides of a fissure are of different polarity and will, therefore, attract iron particles. Cracks may be visible to the naked eye or may be verified by means of a good magnifying glass.

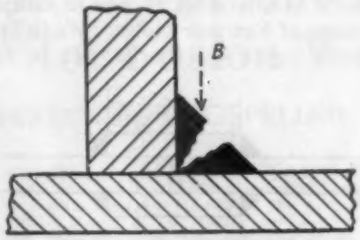


Fig. 5—Checking a Doubtful Weld by Burning Out With a Torch to Disclose the Black Appearance of Parent Material

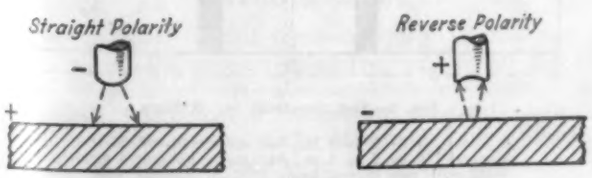


Fig. 6—Checking of Polarity with a Graphite Electrode

When it is doubtful if one is looking at a hair crack or just a fine ripple in the surface of the fillet, drill a ½-in. hole in the weld. A clear line inside of the hole will indicate a crack.

If the materials have fused partially and a slight overlap makes it difficult to judge penetration, then it becomes necessary to remove a section of the weld to make sure of fusion. It can be done quickly by burning out part of the weld. First, cut through the weld, as shown in Fig. 5; then melt the material away, beginning at the outer part (see arrow *B*). The last layer will curl up like a sliver. The heat will not be transferred through a layer of trapped slag to the piece where fusion is missing; the black appearance of the parent metal will be exposed. If a man experienced in handling a torch is not available, a section of the doubtful weld can be chipped out. To prevent destroying the evidence by either peening over the crack or by driving the filler in the parent material, it is necessary to cut through the weld and separate a section. If it can be lifted out to disclose the black appearance of the parent metal, as explained previously, the materials have not fused together.

Checking of Polarity

Work requiring reverse polarity will alternate with jobs that can be welded only with straight polarity, that is, the plus side of the line connected to the work. The polarity can be checked readily with a graphite electrode (refer to Fig. 6). For straight polarity, the carbon end becomes blunt and the arc, in the shape of a pronounced cone, seems to start from the carbon. With reverse polarity, a crater is formed in the carbon and the arc appears to start from the work and is harder to maintain. Welders familiar with one make of wire will notice the increased melting rate of the metal electrode. A pronounced crater in the work will only be possible for straight polarity.

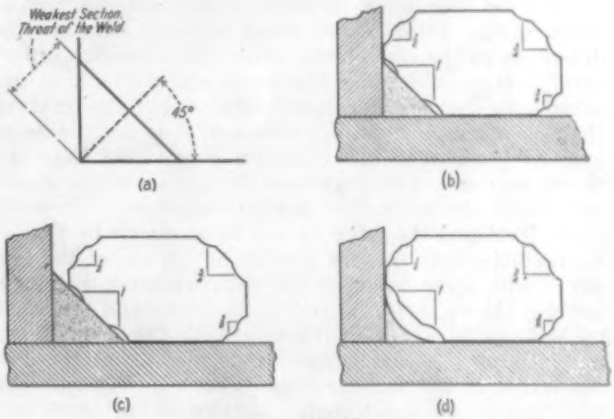


Fig. 7—Use of Welding Gage
(a) Location of weakest section in weld.
(b) Correct size.
(c) Oversize weld.
(d) Undersize weld.

Gages

The operators and the inspectors are provided with fillet welding gages. The throat of the weld, Fig. 7 (*a*), the weakest section of the weld, can readily be checked

by means of a gage. The flat portion of the gage makes contact with the hypotenuse of the fillet, while the two right angle sides rest on the component parts. The corners of the flat portion of the gage are relieved, which permits the use of the gage though the weld might deviate slightly from its ideal form. In the average run of the work, the gage will not always touch both right angle sides, because the welds are oversize,

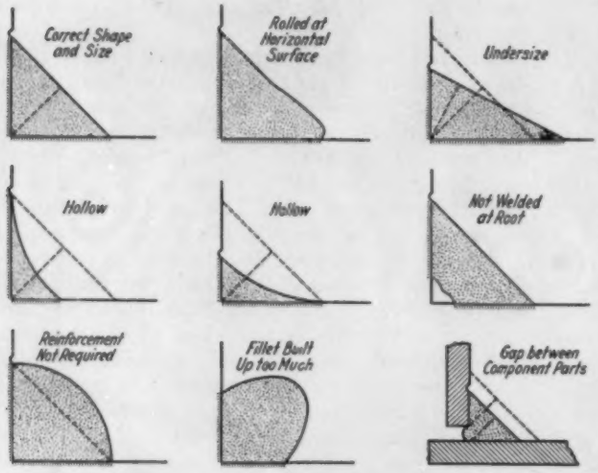


Fig. 8—Various Imperfect Welds Compared with a Satisfactory Weld

as indicated by Fig. 7 (*c*). Fig. 7 (*d*) represents an undersize weld, in which case the flat of the gage does not butt at all on the weld. On this continent, the size of a fillet weld is expressed in terms of the width in inches of its adjacent fused sides. Referring to Fig. 7 (*b*), the two lines in each corner, intersecting at right angles, point to the fused section, given on the drawings as the size of the weld. An excessive difference, particularly along the horizontal surface, is not permissible, because frequently there is less fusion there than on the vertical wall. However, it is acceptable so long as the actual fused section is not less than the throat section. The American Bureau of Welding recommended the method of gaging described. Our company developed the gage in the form shown in Fig. 7. Each of the four corners is utilized. A set of the two gages will cover most of the requirements; one gage takes in the ¼, 5/16, ⅜ and ½-in. fillets, and the other the ⅜, ½, ¾ and 1-in. fillets. With the help of the welding gage, it can be quickly decided about the size and shape of the various fillets shown in Fig. 8. The first fillet is of correct shape; comparing its throat section with those of the other fillets, makes their undersize evident.

TESTING OF WELDERS

Quality of welds depends on the conformity to the drawing, in size and location, and on the extent of fusion of the filler with the parent metal. This is so important that it was found advantageous to test the welders periodically for their ability to deliver the quality desired. These tests are carried on monthly in our company under the supervision of a staff member of the Manufacturing Equipment Department.

The test pieces were devised to check fusion and at the same time permit a measurement of the quality of the weld in terms of tensile strength. Several specimens made up of different thicknesses of material are used. One of these test pieces is shown in Fig. 9. The thickness of the upper and lower strap is automatically a gage of the size of fillets. Four fillets are confined in a small space; the fusion of each one affects the test; the welds are not machined and are, therefore, more comparable to actual shop condition. This is, in addition, an economical advantage which expedites the test and lowers its cost.

A minimum of 40,000 lb. per sq. in. is required from shop welders, while operators for welding of building must pass a minimum test of 45,000 lb. per sq. in.

Signing of Work by Welders

With a large number of welders working in the shop in successive shifts and, frequently, one group continuing the work of the preceding group, it is essential to be able to identify the work of each welder and make him responsible therefor. This is accomplished by assigning each welder a stencil. The welder places his stencil near each weld or at the start and finish of a group of welds.

Qualifications and Selection of Inspectors

Welding inspectors are promoted from the ranks of welders, chosen for their experience and also for the proved reputation of being reliable. They must read blue prints readily, be able to deal with men and have demonstrated their qualifications as mechanics.

In the shop, where the operators are close together and the inspector is familiar with the traits of the welders, he can inspect the work of approximately twenty-five men. It is understood that the inspector needs to watch the operators at intervals only, as good welding becomes a habit to some extent. In building work, about twelve operators is the limit for one inspector; the men are generally scattered on two or three floors and most of them are new to the inspector.

NON-DESTRUCTIVE TESTS

For vessels, like tanks for circuit breakers, regulators and transformers, additional tests are necessary after completion of the welding in order to determine if the welds are oil tight. For mercury-arc rectifiers, part of the welds must be vacuum tight and others water tight. A variety of non-destructive tests were adapted to the application or the equipment available for test.

Water-Gravity Test

The water-gravity test is used occasionally. It does not require much equipment, but is not recommended highly. The water has the tendency to induce rust quickly, which closes fine leaks temporarily. With tests of this type, it is advisable to create vibrations in the vessel by means of hammer blows. Weak spots in welds will frequently break by shocks. It is far better to

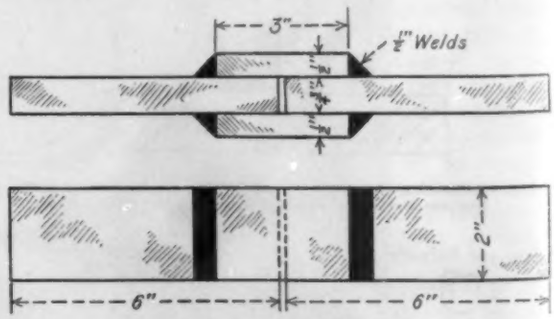


Fig. 9—Test Specimen for Welders

Material:
2 pieces, ¾ by 2 by 6 in., bar stock, hot-rolled steel.
2 pieces, ½ by 2 by 3 in., bar stock, hot-rolled steel.
Weld with two layers, using 5/32-in. welding wire.
Minimum load, 40,000 lb. per sq. in.
Maximum load per test specimen, 56,000 lb

locate them that way, than to wait until stresses from handling of the complete apparatus or during shipment will show up the defects.

Kerosene Tests

Vessels that cannot be conveniently closed for the soap-and-bubble test, which is described later, can be reliably tested with kerosene; its penetrating qualities will show up the most minute leaks on whiting painted over the welds. The drawback of this test is that leaks can only be repaired after the vessel has been emptied and the kerosene burned out of the defective spots.

For testing of large quantities of tanks, it is essential to reduce the manual handling. Methods must be adopted that, at a minimum expense, will prove the tank suitable for its purpose.

Air Test by Immersion

The simplest test is by means of immersion. It can be applied to tanks that do not have to withstand high operating stresses and are made of relatively heavy material. The tank to be tested is placed on a shelf connected by means of uprights and cross bars to a chain hoist. A suitable cover, with packing, is pressed quickly against the tank by means of an air cylinder mounted on the cross bars. The tank is connected to the air pressure line. Any defects in the welds show up by the air bubbles in the water.

High-Pressure Tests

Circuit breaker tanks that have to be not only air tight but must withstand high stresses occurring in a tank during an explosion accompanying a short circuit are put under oil pressures of 150 to 600 lb. per sq. in.

Tests of Tanks Made of Thin Sheet Steel by the Soap-and-Bubble Test and Hot-Oil Test

The test of regulator tanks made of corrugated sheet steel requires a special set up. Many tanks have to be handled, and their material is relatively thin, in order to enable easy forming of the corrugations. There is a large amount of welding on the regulator tank, not only at the top and bottom, but also at the sides, as there are several sheets required in the making of the tank; in addition, nipples must be inserted in the walls. The beads along the top and bottom can only be small and practically amount to a melting down of the sheet material. The tanks are subjected first to a soap-and-bubble test. Air pressure of 5 lb. is used. Regulator tanks are built in large quantities with a steady load the whole year around, which makes it advisable to provide every facility for testing. The tanks are lined on racks. A special top had been worked out, which is handled by a chain hoist, running on a track. The top is pressed on by two cylinders supplied from the air line of approximately 70 lb. The examination by the soap-and-bubble test is so effective that it is rare to discover leaks on the next test, which is carried on under operating conditions. The tanks are filled with oil at approximately 90° C. Tanks are generally removed from the racks after 24 hours; if leaks show up, the time is extended to 48 hours. The pump is used again to return the oil to the large storage tank. The combination of the two tests, namely, the soap-and-bubble test and the hot-oil test proved worth while.

Test of Vacuum-Tight Tanks

The test for vacuum-tight tanks for mercury-arc rectifiers is extremely important. The inside shell and all its connections must hold a vacuum, while the outer shell must be water tight; the space between the two is used for water cooling. The basic law of design, that nothing is acceptable unless it can be tested and repaired, must be very strictly observed with this type of apparatus. All parts for the rectifier are separately tested; in addition, all the vacuum pumps and accessories are subjected to a frequent check up. The inner shell, which holds the vacuum, is first put under the soap-and-bubble test, air pressure up to 80 lb. being used; somewhat less pressure is applied for the shell that holds water only. Under vacuum, the first tank or the assembled apparatus must not show a leakage of one half to one micron per hour, depending on the size of the equipment. A micron is 1/760,000 of an atmosphere.

There is a demand for commercial tests that would eliminate the personal factor in determining the quality of a finished weld. There have been applied X-rays, stethoscope and magnetic measurements. It is too early to decide if these laboratory methods will find use in daily productions.

The Quality of Materials for Fusion Welding

By C. R. TEXTER and F. N. SPELLER

✦ This paper was presented at a symposium on Welding under the auspices of the Pittsburgh Section of the A. W. S. and the Regional Meeting of the A. S. T. M., March 18, 1931. Messrs. C. R. Texter and F. N. Speller are with the National Tube Co., Department of Metallurgy and Research.

INTRODUCTION

THE ideal welded joint obviously is that one in which the properties of the weld metal and the base metal are similar both chemically and physically. Although at the present time this objective does not seem commercially attainable, such an ideal should be kept constantly in mind and investigation pointed in that direction.

In the light of available information the choice of materials for welding apparently does not depend so much upon the process employed as upon welding technique and the careful control of contributing factors such as temperature and pressure, in the case of plastic welding; speed and current density, in the case of electric welding; kind of flame and its proper manipulation, in the case of gas welding; flux used, etc. It is not possible to definitely define all the factors which influence weldability and the statement in some specifications that steel shall be of good weldable quality leaves the manufacturer in somewhat of a quandary.

Subcommittee XXI on Steel for Welding of the Society's Committee A-1 on Steel passed a motion about a year ago with respect to plate material for fusion welding, which was slightly amended January 15, 1931, to read as follows:

1. It was voted that it is not necessary at present to write separate and complete specifications for steel for fusion welding in view of the number of standard specifications under which satisfactory material has been purchased for this purpose.

2. It was voted as the opinion of the committee that steel made under the following A.S.T.M. specifications[1] can be welded satisfactorily by the usual fusion processes now in general use:

A 7 – 29	Structural Steel for Bridges
A 9 – 29	Structural Steel for Buildings
A 113 – 29	Structural Steel for Locomotives and Cars
A 12 – 21	Structural Steel for Ships
A 30 – 24	Boiler and Firebox Steel for Locomotives
A 70 – 27	Boiler and Firebox Steel for Stationary Service
A 78 – 30	Steel Plates of Structural Quality for Forge Welding
A 89 – 30	Steel Plates of Flange and Firebox Quality for Forge Welding
A 83 –30	Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes
A 53 – 30	Welded and Seamless Steel Pipe (with carbon restriction)
A 82 – 27	Cold-Drawn Steel Wire for Concrete Reinforcement
A 106 – 29	Lap-welded and Seamless Steel Pipe for High-Temperature Service
A 129 – 30 T	Open-Hearth Iron Plates of Flange Quality
A 120 – 28T	Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Ordinary Uses

In connection with carbon limitations in these specifications, the committee was of the opinion that, while higher carbon steels are successfully welded, commercial practice at present often limits the carbon (by ladle test) to 0.30 per cent in open-hearth steel and 0.15 per cent in bessemer steel. In the case of seamless steel tubes covered by Specifications A 53, the carbon limit was placed at 0.35 per cent.

BASE METAL FOR WELDING

The kind of metal (steel, wrought iron, Armco iron, Toncan iron, etc.) to be used, of course, is optional with the purchaser and depends to a large extent upon the product desired, but it appears that material produced by the open-hearth process is usually preferred. At the present time, grades A and B of Specifications A 78–30 for steel plates of structural quality for forge welding and A 89-30[2] for steel plates of flange and firebox quality for forge welding have found quite extensive use for all kinds of welding.

A typical specification, prepared by the Board of Water Commissioners of Hartford, Conn., reads as follows:

Steel for welded pipe shall conform to A.S.T.M. A 78 – 30 grade A. Electrodes and filler bars shall have all the properties necessary for making acceptable welds. In general the chemical composition of the filler bars shall be within the following limits:

Carbon	not over 0.200 per cent
Manganese	not over 0.600 per cent
Sulphur	not over 0.055 per cent
Phosphorus	not over 0.060 per cent

Practically all water board specifications refer to Specifications A 78–30 but specifications for welding wire generally are not given.

The 1930 Edition of the American Welding Society Code for Welding of Pressure Piping reads as follows: "The material shall be of good weldable quality, free from non-metallic inclusions, gases and segregations." The Section on Welding of Pressure Piping of the Code of the American Society of Mechanical Engineers reads practically the same with the following addition: "Wrought iron is acceptable under this code." It is quite evident from these examples that the quality of materials for welding is not very definitely defined even by two large societies which are vitally interested.

In the Technical Report for 1929 issued by the British Engine Boiler and Electrical Insurance Co., Ltd.[3] appears the following statement:

The strength of plate which should be used in welded pressure vessels is a question on which there is a division of opinion. Six qualities of plate, namely, of wrought iron, Armco iron and steel with 0.10, 0.22, 0.30 and 0.60 per cent carbon, were welded with a single V-butt weld. The quality of fusion and the change occurring in the plate metal were noted in each case. It was found that there was nothing to choose between the quality of the fusion obtainable with any of the plates and that there was no intrinsic objection to any of the plates used being welded, provided the welded plate is normalized and a good quality of welding rod with the requisite strength is employed.

The pipe industry at the present time, both during manufacture of the commodity and in subsequent installation, utilizes fusion welding to a greater extent than any other industry. Tonnages running into hundreds of thousands annually are involved, and the notable success with which fusion welding is employed is indicative either of a well-perfected technique or of the high quality of steel used, or both.

One manufacturer of electric fusion-welded pipe specifies that for "line pipe" the steel shall be made by the open-hearth process and shall have the following chemical and physical requirements:

Carbon	0.20 to 0.30 per cent
Manganese	0.30 to 0.75 per cent
Phosphorus	not over 0.04 per cent
Sulphur	not over 0.05 per cent
Tensile strength	60,000 lb. per sq. in.
Elastic limit	½ tensile strength
Elongation in 2 in.	30 per cent

Another pipe manufacturer made tension tests on a number of circumferential welds on 24-in. pipe of approximately 0.30 per cent carbon with the following results:

114 tension tests averaged	74,071 lb. per sq. in.
90 that broke in the weld averaged	73,260 lb. per sq. in.
24 that broke outside the weld averaged	76,966 lb. per sq. in.

The chemical analyses of 94 of the samples of pipe averaged:

Carbon	0.299 per cent
Manganese	0.595 per cent
Phosphorus	0.010 per cent
Sulphur	0.026 per cent
Silicon	0.180 per cent

This would average the following in physical properties:

Tensile strength	76,000 lb. per sq. in.
Elastic limit	48,000 lb. per sq. in.
Elongation in 2 in.	35 per cent

Furthermore, in actual field welding of line pipe good practice is obtained with 0.25 to 0.35 per cent carbon and manganese as high as 1.25 per cent, while it is reported by oil companies that 0.30 to 0.40-per cent carbon drill pipe is being successfully welded into line pipe when its usefulness as drill pipe has been outlived. These instances are of sufficiently frequent occurrence to demonstrate the practicability of welding steels with carbon higher than the 0.30 per cent tentatively recommended by Subcommittee XXI.

Good practice has been obtained in the welding of intermediate manganese-steel rails although in this case the weld is not depended upon for strength. Considerable care must be exercised and some difficulty may be experienced but it is reported that intermediate manganese-steel rails were successfully welded by the fusion welding process in Toronto, Canada. The specifications upon which the rails were purchased are as follows:

Carbon	0.60 to 0.75 per cent
Manganese	1.30 to 1.60 per cent
Silicon	0.15 to 0.30 per cent
Phosphorus	not over 0.04 per cent

[1] 1930 Book of A.S.T.M. Standards, Part I; and *Proceedings*, Am. Soc. Testing Mats., Vol. 30, Part I, p. 965 (1930), or 1930 Book of A.S.T.M. Tentative Standards, p. 21.

[2] 1930 Book of A.S.T.M. Standards, Part I, pp. 122 and 127, respectively.

[3] *The Engineer*, Oct. 10, 1930.

Welding rod of not over 0.05 per cent carbon was used.

Experience has shown that the success or failure in fusion welding steel of 0.20 to 0.30 per cent carbon and higher depends upon the use of a suitable flux applied either as a covering over the welding rod or deposited in the groove. The flux not only excludes oxygen but keeps the deposited metal in a fluid state sufficiently long to facilitate the escape of a portion of the dissolved gases.

The percentage and character of non-metallic inclusions in steel very probably have an important influence upon the ease of fusion welding and upon the soundness of the weld. Although the exact mechanism of this influence has not been defined, it is suggested that impurities, especially oxides in steel, rearrange themselves under the effect of heat to form zones of weakness close to, but not in the actual weld. For this reason it is thought that open-hearth steel is better than Bessemer steel, and fire-box quality more adaptable than structural quality. It is, however, more or less an economic question, as with care and experience any of the commercial grades of steel can be satisfactorily welded. For very important structures such as pressure vessels and boilers, the best quality obtainable will be well worth the cost.

Some steels, the chemical composition of which would indicate no difficulty in welding, give trouble. Therefore, some purchasers adhere to the practice of inserting in their specifications the clause that "steel shall be of good welding quality." One consumer (American Car and Foundry Co.) suggests that one of the chief sources of trouble in welding is the presence of laminations, stating that laminations prevent proper penetration and thus cause faulty welds. Greater top discard in the ingot would largely overcome this trouble at some increase in cost of the steel. It should be borne in mind, however, that good welding steel may be ruined by a poor quality of rod or poor workmanship.

Welding Stainless Steels

Welding sooner or later becomes a problem with any new metal. This has been true of copper, nickel, monel metal, aluminum, duralumin and now applies to the various types of stainless steel. The problem has been solved in every case by the development of suitable equipment, fluxes and technique. The ever increasing and more diversified use of chromium and chromium-nickel steels involves considerable welding. Whereas in ordinary steel there exists only the problem of producing a welded joint possessing certain properties of strength, ductility and endurance, in the case of stainless steels it is necessary to know if, and how much, the corrosion-resistance properties of the metal may be affected by the welding operation.

The maximum resistance to corrosion will be obtained, in welding such alloys, by keeping carbon as low as possible, by heat treatment and by removing the welding scale. Heat treatment is not often essential, especially in light-gage material, as these alloys have a high resistance to corrosion in air-cooled condition.

Aside from the possible changes in corrosion-resistance properties of the stainless steels they usually can be satisfactorily welded with certain precautions by ordinary methods of welding now in use. The most frequently used 18 per cent chromium, 8 per cent nickel alloy contains less than 0.10 per cent of carbon.

Welding Wire and Electrode

The selection of the proper welding wire or electrode metal is shrouded in considerable mystery. There are a great number of proprietary articles on the market. In the early days of welding, the idea was prevalent that nothing but Swedish iron welding wire could be used with any degree of satisfaction. Swedish iron is a low-carbon pure iron with about one per cent of silicate inclusions and although its use results in very acceptable welds, special grades of steel are just as satisfactory for some purposes and for other purposes considerably better.

A good rule to follow in the selection of welding rod or electrode is to match the quality of rod with the quality of plates being joined. It does not follow, however, that if low tensile strength rod is used to join higher tensile strength plates, the weld will be relatively weak, because the weld metal derives a definite increase of strength from the plate metal which it is used to unite due to carbon diffusion, and the practice of using soft welding rod is probably based on this principle.

Complete chemical or physical specifications for welding wire are practically impossible to write and may be undesirable until more data are available. This applies to the wire used in both gas welding and arc welding. At the present time the most that can safely be said is that the wire should be capable of making sound and acceptable welds.

For metallic arc welding, the American Welding Society in its *Bulletin No. 2* on Welding Wire Specifications specifies two grades of low-carbon iron or steel electrodes—Grade E 1-A containing not over 0.06 per cent carbon and not over 0.15 per cent manganese, and Grade E 1-B containing 0.13 to 0.18 per cent carbon and 0.40 to 0.60 per cent manganese—and states that either Grades E 1-A or E 1-B may be used satisfactorily for welding mild steel structural plates, shapes, bars, or low-carbon steel forgings and castings.

This bulletin also specifies a high-carbon grade, E 1-C, containing 0.85 to 1.10 per cent carbon and 0.30 to 0.60 per cent manganese for use in welding high-carbon steel.

This bulletin also recommends for gas welding one grade, G 1-A, containing not over 0.06 per cent carbon and not over 0.15 per cent manganese, for use in welding mild steel structural shapes, plates, bars, and low-carbon steel forgings and castings.

Whatever the quality of wire selected, it is of considerable importance that its surface be free of all foreign matter, such as dirt and scale, that may fuse with the weld metal and cause faulty welds. It is for this reason that much of the wire used for ordinary welding is copper coated. The process of coppering removes drawing compounds and scale.

For the welding of many steels it is found advantageous to use welding wire covered with adequate flux. This is particularly true in the case of the stainless steels. For instance, the electrode used in metallic arc welding of 18 per cent chromium, 8 per cent nickel low-carbon alloy should be so coated that a reducing atmosphere will be produced around the arc or otherwise the weld metal may be oxidized and a porous weld result. Furthermore, the coating must be free of carbon as the weld metal readily absorbs carbon with a resulting decrease in corrosion resistance.

CORROSION OF FUSION WELDS

Where corrosive conditions exist, the question arises as to whether the weld may corrode more rapidly than the base metal, or whether the one might not accelerate the corrosion of the other in the presence of an electrolyte. At the present time no material difference has

been found. If the weld metal contains fissures or surface discontinuities there is the possibility of the establishment of an electrolytic cell. Furthermore, electrolytic action may result if the weld metal possesses a radically different potential from that of the base metal or if the magnetic oxide scale on the weld differs from that on the adjacent metal. In corrosive water this may result in corrosion of the base metal adjacent to the weld or vice versa. More data are needed on this question.

SUMMARY

The problem before us seems to be the selection of the proper materials for definite uses and the development of a correct procedure in every instance. Welding technique will determine to a very great extent the quality of a weld. Given the same plate and welding rod, one procedure may result in a perfect weld while another may produce a weld showing incomplete penetration, numerous gas cavities and other defects. Experience indicates that when the proper technique has been developed, satisfactory welds can be obtained with reasonably good material provided one quality of plate and one quality of welding rod are used. Therefore, perhaps a modified procedure should be followed for each set of conditions. Carrying this thought to its logical conclusion, it is obvious that as few combinations as possible, in the way of base metal and rod, be employed. In the case of electric arc welding, for any given plate to be joined there is a best type and size of electrode, an optimum current through the arc and a correct potential. In the case of gas welding, the character of the flame (oxidizing or reducing) and its proper application are very likely of first importance. The welder, of course, must be capable of appreciating these variables and of adhering to what has been found to be the best practice. Therefore, standardization of base metal, welding wire and electrodes should be our keynote and every effort made to encourage the development of better materials, more experienced personnel and better facilities for welding.

An intensive study of the chemistry of the open-hearth process now being sponsored by the Metallurgical Advisory Board in Pittsburgh, including representatives of the United States Bureau of Mines, Carnegie Institute of Technology and steel manufacturers, may have an important bearing upon the quality of metal for welding. The main object of this investigation is the production of more uniformly clean steel at low cost.

At the present time it seems that the recommendations made by the committee regarding base metal should be noted on standard specifications. It should be recognized that in many of the specifications now being used the purchaser has two or three qualities of each grade of steel from which to select, and his choice will be determined by the importance of the work and economic considerations. The problem of formulation of welding wire specifications has been delegated to Subcommittee XXI, and this subject will be taken up, with the full cooperation of the American Welding Society, as soon as proper representation of those interested is obtained on this committee.

Acknowledgments.—Acknowledgment is due to J. R. Dawson, Union Carbide and Carbon Research Laboratories, J. H. Nead, American Rolling Mill Co., and F. O. Leitzell, Blaw-Knox Co., members of Subcommittee XXI of the Society's Committee A-1 on Steel, and G. O. Carter, Linde Air Products Co., who have assisted in the preparation of this paper by reviewing and making helpful suggestions.

Tests on Flame-Cut Wind Connections

By OTIS E. HOVEY

✦ Reprinted from April 30 issue of Engineering News-Record. Mr. Hovey is Assistant Chief Engineer, American Bridge Co., New York City.

THE SUBJECT of flame-cutting of structural details for wind connections for building frames has been one of considerable interest for several years. In 1928 the American Bridge Co. made and had tested at the Bureau of Standards six sample connections similar to those being used in a forty-four-story building in New York City, to determine whether wind connections flame-cut and then punched were superior to those punched and then flame-cut. The results did not show any difference between the two methods of fabrication.

Subsequently certain tests were made by Columbia University (publication No. 3, July, 1929), which were interpreted by their makers to indicate a risk of brittleness in pieces flame-cut after punching. As a result, the alleged damage by flame-cutting has been in controversy, and the American Bridge Co. determined to make another series of tests in order to develop more data in relation to the effects of various methods of fabrication.

The 1930 samples were cut from a single 24-in. 105.9-lb. I-beam of normal structural quality but rather softer than average. The samples were duplicates of flame-cut wind connections used in the Empire State Building in New York City, except that extensions having parallel sides were used beyond the theoretical ends of the tapered webs for convenience in testing. In each sample the pieces bolted together

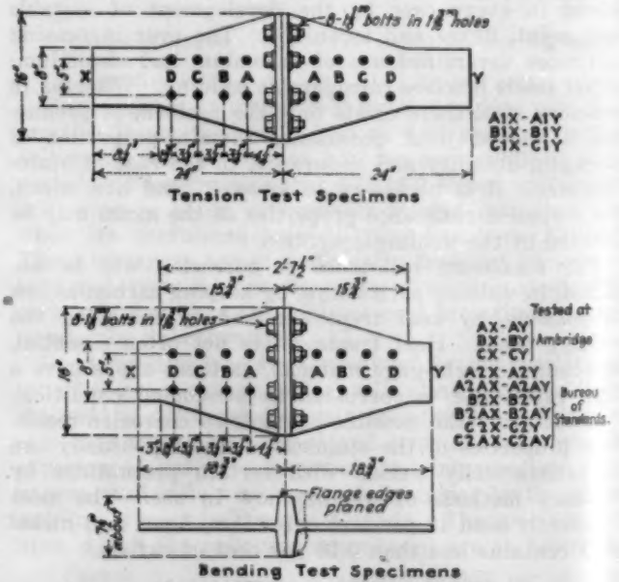


Fig. 1—Flame-Cut Test Specimens

A specimen; holes punched, edges then flame-cut. *B* specimen; holes drilled, edges then flame-cut. *C* specimen; holes punched, edges then flame-cut and planed

were cut from opposite flanges of the beam, designated by the letters *X* and *Y*. Fig. 1 shows the details of the three tensile specimens and also gives details of the nine samples which were subjected to transverse bending.

The method of fabrication is indicated by the first letter of the marks on the specimens: *A*, holes punched, edges then flame-cut; *B*, holes drilled, edges then flame-cut; *C*, holes punched, edges then flame-cut and finally planed off ¼ in.

Impact-Bend Test

Impact-bend tests were made in the company's shop at Ambridge, Pa. The three specimens listed in Fig. 1 were given a transverse test by dropping a 4500-lb. hammer 12 in. One blow in each case was sufficient to drive the specimen down to the bottom of a die block with a resulting deflection of about 7⅜ in. on a span of 2 ft. The die side of the punched specimens and the burr side of the drilled specimens were on the lower or convex side of the bends. The greatest bending occurred in the holes nearest the flange; and cracks appeared at the die side of these holes in specimens *A* and *C*. The drill burrs had not been removed on the *B* specimens, and very minute cracks were visible in the burrs of the holes nearest the flanges. No cracks were visible in the edges of the flame-cut webs of any of the specimens.

Fig. 2—Bend-Test Specimens
Extreme bending was produced in a press after the specimens had been subjected to an impact-bend test involving the dropping of a 4500-lb. hammer 12 in.

The bending was continued in a press until the specimens were bent as shown in Fig. 2. There was very little change in the size of the cracks from the press bending, and no cracks were visible in any of the flame-cut edges.

Tension Tests

Tension and static-bend tests were made at the Bureau of Standards, Washington. The tension specimens were prepared by filing off all burrs flush with the surface of the webs, taking care not to round the edges of the holes. Tensile load was applied slowly, so that it was easy to observe either Lüder lines or cracks. The Lüder lines were first seen around and between the holes farthest from the flanges and then became visible successively at the other lines of holes. The fractures were good; they began at the sides of the holes and then progressed to the edges and middle of the specimens.

Static-Bend Tests

Static-bend tests were made as shown in Fig. 3. Loading began with a load of 2000 lb. and increased until the yield point had been exceeded on each of the eighteen 2-in. gage lines on each of the specimens. Then the samples were further bent to determine the load producing the first visible crack. Cracks appeared first in the holes nearest the flanges of the four samples having punched holes. The cracks were in the die side of the holes in the small offset collars that are characteristic of holes punched in material about ⅝ in. thick. There were no cracks in the *B* specimens having drilled holes. None of the specimens was found to have cracked at the flame-cut edges.

Finally, the specimens were set upright in the machine and squeezed together as bent columns. Cracks appeared in other holes; the greatest bending and largest cracks now occurred in the second line from the flange. With the exception of one very small crack in one of the holes of the *B* specimens no cracks occurred in the drilled holes. There were no cracks in the flame-cut edges of any of the specimens.

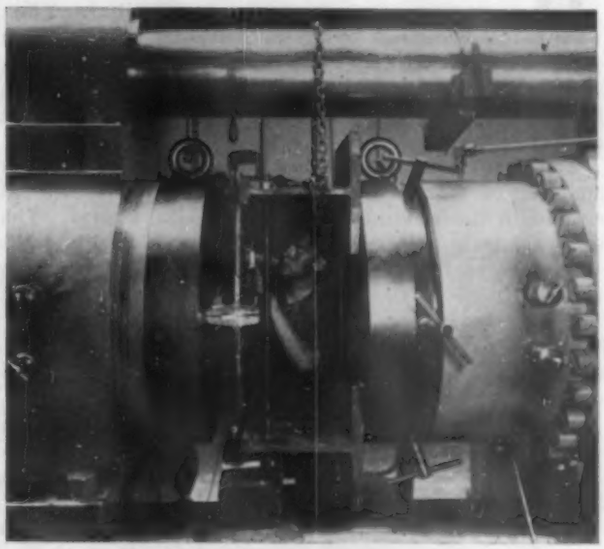


Fig. 3—Set-Up for Static-Bend Test

Summary of Results

1. The fractures started at the sides of the holes and not at the flame-cut edges.
2. All three specimens had about the same yield point.
3. The specimens with drilled holes had greater ultimate strength, elongation and reduction of area than those with punched holes.
4. Planing the flame-cut edges did not increase either yield point or ultimate strength.

The bending tests showed that:

1. No cracks occurred in any of the flame-cut or flame-cut and planed edges.
2. Load-deflection values and stress distribution were about the same for the different types of specimens.
3. Small cracks occurred in the die side of the punched holes, but only after the connections had been visibly and permanently deformed. The first cracks appeared when the average load on the specimens was 186 per cent of the yield-point. No cracks were found in any of the drilled holes until an extreme deformation was reached, and then only 1 minute crack appeared.

The writer believes that the results indicate satisfactory quality in the flame-cut connections.

A Welded Dwelling House

By B. S. HAVENS

✦ B. S. Havens, News Bureau, General Electric Co., Schenectady, N. Y.

WHAT is probably the first completely welded brick and steel dwelling constructed by electric arc welding was recently built for and is now being occupied by C. E. Anthony of Larchmont Gardens, New York. It is a six-room, two-story building, 32 ft. by 26 ft., with full basement and a two-car basement garage, and is built on a foundation of stone and concrete.

The entire framework and all interior partitions were made up of standard size panel frames previously fabricated in the welding shop from 1½-in. angles. They were made up of two duplicate frames tied together with spacers to provide the regular wall thickness of 4 in. throughout the house. Two sizes were used, the wall sections in which there are no windows being 2 ft. by 9 ft. The window sections are 6 ft. by 9 ft., of sufficient size to accommodate any window normally used in a dwelling house.

In erecting the walls and partitions, a plate sill 6 in. wide by ¼ in. thick was laid directly on the foundation to take care of any roughness on the concrete, and fastened down by means of bolts grouted in the concrete. The fabricated panels were then welded to the sill. Adjoining panels were welded together at their edges to make a solid structure throughout. The second floor was erected in exactly the same manner and was welded to the top of the first floor sections.

An 8-in. I-beam was used for the main floor bearing beam. All floor joists, on both the first and second floors, are of steel truss construction, 8 in. deep, and welded to the frame of the house at each end and to the bearing beam or partitions in the middle. This type

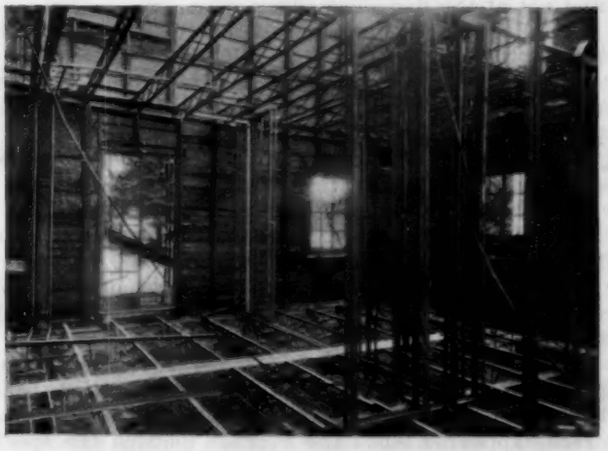


Fig. 1—Interior View, Construction Well Along, Showing Metal Framework and Lining of Walls

of floor beam was used because it provides rigidity without excess material. Steeltex, a 2-in. wire mesh spot welded at each juncture and interwoven into fire-resisting, waterproof paper, is laid directly over the floor joists and covered with a 2-in. course of concrete to make up the floor.

The roof supports or rafters are 4-in. channels with 2-ft. spacing and are welded directly into the outside wall framework of the building. The gable sections were fabricated in the shop, trucked to the building site, hoisted into place and welded to the framework proper. The roof covering consists of Steeltex placed directly over the rafters and covered with a 2-in. layer of Nailcret, a concrete asbestos composition of such characteristics that nails can be driven into it for laying shingles. A layer of slate shingles was used.

Fig. 2—First Floor Metal Framework in Place, and Part of Second Floor Framework Up

The outside of the house is finished off with a brick veneer inside which is placed a layer of Steeltex, to the top of the second floor level. The gables and dormer are finished with stucco. All windows are of the steel casement type welded into the framework of the building. All doors are of Kalman steel construction, set in steel bucks and frames welded into place.

The interior finish of the house consists of Steeltex over the framework, and hard plaster. In fastening the Steeltex in place attachment bars consisting of small rolled steel channels with wire fasteners spot welded to it were used. The channels are securely tack welded to the steel framework and the Steeltex tied in place by means of the wires.

The floors are covered with Armstrong inlaid linoleum with a felt backing on both the first and second floors. The stairways are steel with ornamental iron railings, welded in place, and have Sutterlith treads—a composition of plaster of paris, cement and sawdust. All baseboards are also made of this material. Each room is equipped with ornamental iron lighting fixtures.

The interior and exterior appearance of the house are no different from that of any other similar house. The lower floor is laid out with a living room, dining room, kitchen and vestibule. The second floor has three bedrooms, a bathroom and ample closet space. In the basement, welded construction was also used in the installation of a welded oil burning furnace and a welded hot water heater.

Many advantages are claimed for the welded type of construction, among them being the following: rapidity and noiselessness of construction; use of standard panels; flexibility of design; fireproof construction, giving lower insurance rate; rigidity and solidity, eliminating vibration, low rate of depreciation and soundproof walls.

Welded Bridges and Buildings

THESE statistics were gathered by the Committee on Building Codes of the American Welding Society. The information was furnished on regular forms of the committee. The accuracy and responsibility for the statistics furnished depends upon the individual contributors.

BRIDGES

Illinois

Railway bridge—vertical left bridge—1 span. All connections arc welded. Two sheave wheels reinforced to remedy loosening at bearing on hubs. Load on one wheel about 500 tons. Location—Chicago, Ill. Owner—Pennsylvania R.R. Reinforcement of existing structure.

Massachusetts

Railway, freight service—Warren truss, subdivided —1 span—width of truss 17 ft.—length of truss—134 ft. 8 in.—tonnage 80. All connections arc welded in shop. One track—Skew bridge—Live loading Cooper's E-50. Location—Chicopee Falls, Mass. Owner—Westinghouse Elec. & Mfg. Co.

New Jersey

Trolley and vehicle—Pony trusses—2 spans—width of trusses 20 ft.—length of trusses 85 ft. each span—24 tons new steel added—all connections arc welded in field. Rehabilitation of existing structure. Location—Bound Brook, N. J. Owner—Public Service Coordinated Transport Co.

Highway bridge—New structure—223 tons welded battledeck floor. Field welded. Battledeck floor used only on lift span. Location—Burlington, N. J.—Bristol, Del. Owner—McClintic Marshall Co.

Four track viaduct—Plate girder—60 spans—approximate dimension of bridge 3960 ft. x 44 ft.—width of girders 5 ft.—length of girders—approximately 56 ft.—56 tons new steel added. All connections arc welded in field. A few connection angles were replaced by riveting. All work at new bases was welded. Completed March, 1930. Location—Jersey City, N. J. Owner—Pennsylvania R.R.

Railroad bridge—high truss, draw bridge—1 span—width of truss 10 ft.—length of truss 80 ft.—½ ton new steel added. All connections arc welded in field. Rehabilitation of existing structure. Location-Ocean City, N. J. Owner—The Reading R.R. Co.

Railroad bridge—low truss—1 span—width of truss 8 ft.—length of truss 50 ft.—2 tons new steel added. Reinforcement of existing structure. All connections arc welded in field. Location—Summit, N. J. Owner—Rahway Valley R.R., N. J.

New York

Railroad bridge—open deck girders—all connections arc welded in field. Bottom flanges at bearings were renewed by means of plates which were arc welded to vertical legs of bottom flange, angles and web. Location—Brooklyn, N. Y. (Atlantic Ave. Viaduct). Owner—Long Island R.R. Co.

Railroad bridge—No. 32.10—lattice truss type—through span—width of trusses 15 ft.—length of trusses 140 ft.—12½ tons new steel added. All new materials arc welded in field. Bridge over creek. Reinforcement of existing structure. Location—Hillburn, N. Y. Completed September, 1929. Owner—Erie R.R.

Railroad bridge—high truss—1 span—width of truss 12 ft.—length of truss 100 ft.—10 tons new steel added. All connections arc welded in field. Reinforcement of existing structure. Location—Jamestown, N. Y. Owner—Erie R.R. Co.

Railroad bridge—5 open deck girders; 2 half-through, open deck girders. 5 single spans, 2 double spans—width of girders 5 ft. 6 in.—length of girders 50 ft.-80 ft. 14 tons new steel added. Reinforcement of existing structure. All connections arc welded in field. Location—Montauk Division, L. I., N. Y. Owner—Long Island Railroad Co.

Railroad bridge—high truss—1 span—width of truss 12 ft.—length of truss 100 ft.—About 20 tons new steel added. All connections arc welded in field. Reinforcement of existing structure. Location—Salamanda, N. Y. Owner—Erie R.R. Co.

Bridge M1 to carry street over railroad track—Plate girders—1 span, 5 girders—approximate dimension of bridge 30 ft. x 50 ft. long—width of girders approximately 10 ft.—length of girders 30 ft.—2 tons new steel added. Arc welded in field. Reinforcing cover plates of bottom chords. Completed August, 1929. Location—New York, N. Y. Owner—N. Y. C. R.R.

Bridge M4A—Plate girders—1 span, 107 girders—approximate dimension of bridge 30 ft. x 600 ft. long—width of girders approximately 5 ft.—length of girders 30 ft.—27 tons new steel added. All connections arc welded in field. Reinforcing cover plate of bottom chords. Location—New York, N. Y. Owner—N. Y. C. R.R. Completed July, 1929.

Bridge to carry street over railroad track—Plate girders—1 span, 22 girders—approximate dimension of bridge 30 ft. x 120 ft. long—width of girders approximately 5 ft.—length of girders 30 ft.—5 tons new steel added. All connections arc welded in field. Reinforcing cover plates of bottom chord. Completed July, 1929. Location—New York, N. Y. Owner—N. Y. C. R.R. Bridge M8.

Bridge to carry street over N. Y. C. R.R. track—Plate girder—3 spans—approximate dimension of bridge 60 ft. x 117 ft.—width of girders 37 ft.—length of girders between supports 16 ft.—8 tons steel. All connections arc welded in field. New reinforcing plates on bottom chords of floor beams and repairing web plates of girders where corroded. Location—Morris Heights, New York, N. Y. Owner—N. Y. C. R.R. Completed October, 1929.

Bridge to transfer railroad cars from barges to railroad yard—Pony span—Warren truss—1 span—width of trusses 31 ft. 7 in.—length 99 ft.—6 tons steel—Arc welded in field. All reinforcing welded. Completed February, 1930. Location 72nd Street and North River, New York, N. Y. Owner—N. Y. C. R.R.

Double-decking of the Manhattan Bridge—both sides. Owner—City of New York.

Elevated railroad 4 track—Plate girders—length of girders 55 ft. to 60 ft.—224 tons steel. Arc welded in field. All new materials welded. Reinforcing 200 street columns. Replace 3000 stop plates in trough. Location—110th to 129th Sts., New York, N. Y. Owner—N. Y. C. R.R.

Elevated railroad 4 track and station—Plate girders—9 spans—length of girders 55 ft. to 60 ft.—78 tons new steel added. Arc welded in field. All new materials welded. Reinforcing girders. Reinforcing 48 sidewalk columns. Reinforcement of existing structure. Location—124th to 126th Streets, New York, N. Y. Owner—N. Y. C. R.R.

Elevated railroad and station—Plate girders—length of girders between supports 50 ft. to 60 ft.—104 tons new steel added. Arc welded in field. All new materials welded. Reinforcing 139 columns under track from Harlem River to Mott Haven Yard. Location—138th Street, New York, N. Y. Owner—N. Y. C. R.R.

Ohio

Railroad bridge—open deck girders—2 spans—width of girders 6 ft.-6 in. Length of girders 95 ft., 105 ft.—36 tons new steel added. All connections arc welded in field. Reinforcement of existing structure. Location—Akron, Ohio. Owner—Erie Railroad Co.

Railroad bridge—lattice truss type—through span—width of trusses 15 ft.—length of trusses 140 ft.—26 tons new steel added. Arc welded in field. Reinforcement of existing structure. Bridge over creek at Ashland, Ohio. Owner—Erie R.R.

Railroad bridge—lattice truss type—through span—width of trusses 15 ft.—length of trusses 140 ft.—20 tons new steel added. Arc welded in field. All new materials welded. Railroad bridge over creek at Caledonia, Ohio. Completed October, 1930. Owner—Erie R.R.

Railroad bridge—lattice truss type—through span—width of trusses 15 ft.—length of trusses 140 ft.—27 tons new steel added. Arc welded in field. All new materials welded. Reinforcement of existing structure. Bridge over creek at Pavonia, Ohio. Owner—Erie R.R.

Pennsylvania

Outdoor crane runway—girders, columns and bracing—width of girders 73 ft. 3 in.—total length of girders 294 ft.—Tonnage 189. All connections arc welded. Location—E. Pittsburgh. Owner—Westinghouse Elec. & Mfg. Co.

Railroad trestle bridge No. 13.75—girder type—width of girders 13 ft.—average length 31 ft.—24 spans—47 tons steel. Arc welded in field. All reinforcing materials welded. Location—Millerton, Penn. Owner—Erie R.R.

Bridge for carrying street car and vehicle traffic over Monongahela River known as 22nd St. Bridge—Viaduct—all connections arc welded. Reinforcement of existing structure. Location—Pittsburgh. Owner—City of Pittsburgh.

Railroad bridge—open deck girders—32 spans—7 tons new steel added. All connections arc welded in field. Location—Portland, Pa. Owner—Lehigh and New England R.R. Co.

Railroad bridge—high truss—7 spans—width of truss 12 ft.—Length of truss 100 ft.—2 tons new steel added. All connections arc welded. Rehabilitation of existing structure. Location—Rupert, Pa. Owner—The Reading R.R. Co.

Railroad trestle bridge No. 15.11—girder type—16 spans—width of girders 13 ft.—average length 31 ft. 22 tons new steel added. Arc welded in field. All reinforcing materials welded. Location—Trowbridge, Pa. Owner—Erie R.R.

Railway, freight service—through plate girders—1 span—width of girders 15 ft.—length of girders 55 ft.—Tonnage 20. All connections arc welded in field. Location—Turtle Creek, Pa. Owner—Westinghouse Elec. & Mfg. Co.

Tennessee

Mississippi River highway and railway crossing—Total width of trusses—about 70 ft.—total length of trusses—about 4800 ft.—2-13 ft. roadways widened about 2 ft. Rivets used where old holes could be used. Strengthening of truss brackets and miscellaneous connections by arc welding. Location—Memphis, Tenn. Owner—State of Tennessee nd Arkansas.

Texas

Highway Bridge—Deck Plate—75 tons welded battledeck floor. 161 ft. Swing Span with battledeck floor. Location—Port Arthur, Tex. Owner—County.

Virginia

Supporting pipe lines across Jackson River—Low truss—2 spans—width of truss 5 ft.—length of truss 75 ft. 2½ tons new steel added. All connections arc welded in field. Reinforcement of existing structure. Location—Covington, Va. Owner—West Virginia Pulp & Paper Co.

Washington

Railroad bridge—deck girder—5 spans (2-15 ft., 2-32 ft. and 1-51 ft.)—74 tons new steel added. Arc welding used to fasten reinforcing cover plates to girders and columns. Work consisted of triangle shaped area extension to elevated terminal viaduct in which some of existing girders and columns were reinforced by welding cover plates. Welding done in field and completed about December, 1929. Location—Spokane, Wash. Owner—O. W. R.R. & N. Co., and C. M., St. P. & P.

Canada

Heavy commercial traffic—Bow string type of truss. Reinforced concrete—Single span-width of trusses 41 ft.—length of trusses 146 ft. clear span—1800 tons total weight concrete and steel. 240 tons reinforcing steel. Reinforcing rods welded 60 deg. double bevel instead of lapped. All tie rods on tie beams. All through rods and spirals on booms and rods in hangers. New structure. Location—Montreal, Quebec. Owner—City of Montreal.

BUILDINGS

California

One-story building at Berkeley, Cal. Built by Berkeley Construction Co. Dimensions, 50 ft. by 250 ft. Has two 10-ton cranes.

A 60,000 sq. ft. automotive shop for the Associated Oil Co. at Emeryville, Cal., erected in 1928.

Forest Lawn Memorial Park Assn., Glendale, Cal.—Mausoleum. Width 30 ft. Length 96 ft. Span of trusses, maximum 95 ft. Tonnage about 400. New steel added 125 tons. All connections field arc welded. Contains heaviest welded truss on record—60 tons.

Pacific Mutual Life Ins. Co., Los Angeles. Office building annex. Six stories. Tonnage 240. Shop work riveted. Column connections field welded. Minor connections field bolted.

Southern California Edison Co., Los Angeles.—Office building. Ground area about 20,000 sq. ft. Cross floor area 273,000 sq. ft. Height 169 ft. 12 stories. Tonnage 3537. Erection bolts used. Shop work riv-

eted. Building about 75 per cent arc welded. Welding used for earthquake bracing. 70,300 lineal feet of welding.

One-story warehouse, 100 ft. wide, 220 ft. long, with a 10-ft. lean-to on one side, arc welded in 1928 for Capital Rice Mills, Sacramento, Cal. Building has two main aisles on steel columns supporting roof trusses with 50-ft. spans.

San Francisco Harbor Board, San Francisco, Cal.—Ship loading dock. 15 tons welded battledeck floor. Field welded.

Colorado

Midwest Steel and Iron Works Co., Denver, Col.—Office building. Width 28 ft. Length 90 ft. 23 tons battledeck floor welded.

Connecticut

General Electric Co., Bridgeport, Conn.—Storage warehouse. Width 101 ft. 5 in. Length 192 ft. 10 in. Height 47 ft. Five stories. Tonnage 355. All connections arc welded.

Thames River Steam Power Plant of Eastern Connecticut Power Co., Montville, Conn., provided in 1929 with additional steel wind bracing arc welded. Building 60 ft. wide by 147 ft. long.

Yale University, New Haven, Conn.—Library, Book Tower only. Area 9600 sq. ft. per floor. Height 130 ft. 18 low stories. Tonnage 700. All field work arc welded. Erection bolts used.

Raybestos Co. Laboratory building, Stratford, Conn. Width 50 ft. Length 100 ft. Height 24 ft. Tonnage 29. One story and mezzanine. The mezzanine framing carried 10 tanks 7 ft. diameter x 42 ft. long. Two bolts used at each connection for erection purposes. All connections arc welded.

Delaware

Wilmington, Del.—Addition to office building. L-shaped. Lengths of legs 184 ft. and 95 ft. Width 45 ft. Height 194 ft. 4 in. 14 stories. 2-trusses 42 ft. 8 in. 1576 tons new steel added. Erection bolts used. Ends of trusses arc welded to columns and girders.

District of Columbia

Washington, D. C.—Library of Congress. Area 40,000 sq. ft. floor. 181 tons welded battledeck floor. Field welded.

Florida

American Fruit Growers—Avon Park, Fla.—Fruit packing house. Width 100 ft. Length 150 ft. Height 35 ft. One story. Span of trusses 100 ft. Tonnage 82. All connections arc welded. Tack welds used in erection.

L. Maxcy, Inc., Avon Park, Fla.—Citrus Packing House. Width 100 ft. Length 150 ft. Height 37 ft. Span of trusses 100 ft. Welded arches. Tonnage 85. All connections arc welded in field. Tack welds used in erection.

Conners Packing Co., Bartow, Fla.—Fruit packing house. Width 80 ft. Length 150 ft. Height 27 ft. One story. Span of trusses 80 ft. Tonnage 33. All connections arc welded in field. Tack welds used in erection.

Bradford County School Board, Brooker, Fla.—School Auditorium. Width 45 ft. Length 60 ft. Height 23 ft. Span of trusses 45 ft. Tonnage 6. All connections arc welded in field. Tack welds used in erection.

Southern Sugar Co., Clewiston, Fla.—Garage. Width 50 ft. Length 100 ft. Height 20 ft. Span of trusses 50 ft. Tonnage 20. All connections arc welded in field. Tack welds used in erection.

Dundee Citrus Growers Assn., Dundee, Fla.—Fruit packing house. Width 96 ft. Length 165 ft. Height 33 ft. One story. Span of trusses 96 ft. Tonnage 65. All connections arc welded.

W. J. Howey Co., Howey-In-The-Hills, Fla.—Citrus juice plant. Width 32 ft. Length 72 ft. Two stories. Span of trusses 32 ft. Tonnage 15. All connections arc welded in field. Tack welds used in erection.

Ridge Canning Co., Lake Wales, Fla.—Canning plant. Width 100 ft. Length 200 ft. Height 32 ft. Span of trusses 100 ft. Tonnage 95. All connections arc welded. Tack welds used in erection.

Herlong & Co., Leesburg, Fla.—Citrus packing plant. Width 74 ft. Length 215 ft. Height 26 ft. Span of trusses 74 ft. Tonnage 95. All connections arc welded in field.

Brilles Bros., Leesburg, Fla.—Garage. Width 80 ft. Length 100 ft. Height 24 ft. Span of trusses 80 ft. Tonnage 20. All connections arc welded in field.

City of Mt. Dora, Fla.—Municipal Auditorium. Width 50 ft. Length 90 ft. Height 35 ft. Span of trusses 50 ft. Tonnage 15. All connections arc welded in field.

Firestone Sales Co.—Orlando, Fla.—Service station. Width 118 ft. Length 126 ft. Height 17 ft. Span of trusses 50 ft. Tonnage 40. All connections arc welded in field.

Haler—Orlando, Fla.—Garage (Chevrolet). Width 65 ft. Length 135 ft. Height 22 ft. Span of trusses 65 ft. Welded arches. Tonnage 30. All connections arc welded in field.

E. Tiedke—Orlando, Fla.—Garage (Chrysler). Width 50-75 ft. Length 231 ft. Height 21-24 ft. Span of trusses 50-75 ft. Tonnage 40. All connections arc welded in field.

Haler—Orlando, Fla.—Garage (Nash). Width 72 ft. Length 161 ft. Height 22 ft. Span of trusses 72 ft. Welded arches. All connections arc welded in field.

J. H. Hughes & Son, Orlando, Fla.—Garage. Width 70 ft. Length 80 ft. Height 23 ft. Span of trusses 70 ft. Welded arches. Tonnage 20. All connections arc welded in field.

Nixon Butt Packard Co., Orlando, Fla.—Garage. Width 40 ft. Length 80 ft. Height 12 ft. Span of trusses 40 ft. Welded arches. Tonnage 5. All connections arc welded in field.

Orlando Auto Body Works, Orlando, Fla.—Shop. Width 60 ft. Length 80 ft. Height 22 ft. Span of trusses 60 ft. Welded arches. All connections arc welded in field.

Dr. P Philips Co., Orlando, Fla.—Citrus juice plant. Addition to. Width 50 ft. Length 100 ft. Height 16 ft. Span of trusses 50 ft. Tonnage 5. All connections arc welded in field.

Dr. P. Philips Co., Orlando, Fla.—Citrus Packing house. Width 150 ft. Length 202 ft. Height 45 ft. Span of trusses 120 ft. Tonnage 230. All connections arc welded in field.

St. James Catholic School, Orlando, Fla. Reinforcement of existing building. Two stories. Tonnage 5. All connections arc welded in field. Tack welds used in erection.

Seminole County School Board, Ovieda, Fla.—Gymnasium (Open Air). Width 42 ft. Length 140 ft. Height 20 ft. Span of trusses 42 ft. Tonnage 20. All connections arc welded in field.

Alexander & Baird Co.—Pierson, Fla.—Citrus packing plant. Width 65 ft. Length 135 ft. Height 25 ft. Span of trusses 65 ft. Welded arches. Tonnage 30. All connections arc welded in field.

American Fruit Growers, Inc.—Walsingham, Fla.—Citrus Packing House. Width 100 ft. Length 175 ft. Height 32 ft. Span of trusses 100 ft. Tonnage 82. All connections arc welded.

Laus Garage, Winter Garden, Fla. Width 60 ft. Length 60 ft. Height 25 ft. Span of trusses 60 ft. Welded arches. Tonnage 7. All connections arc welded in field.

S. J. Sligh Co.—Winter Garden, Fla.—Citrus Packing Plant. Width 84 ft. Length 225 ft. Height 35 ft. Span of trusses 84 ft. Tonnage 110. All connections arc welded in field.

Bordo Products Co.—Winter Haven, Fla.—Citrus Canning Plant. Width 90 ft. Length 200 ft. Height 30 ft. Span of trusses 90 ft. Welded arches. Tonnage 80. All connections arc welded in field.

De Witt Taylor, Winter Haven, Fla.—Garage. Width 90 ft. Length 100 ft. Height 29 ft. Span of trusses 90 ft. Welded arches. Tonnage 65. All connections arc welded in field.

Farm & Grove Supply Co., Winter Haven, Fla.—Warehouse. Width 45 ft. Length 212 ft. Height 12 ft. Span of trusses 45 ft. Tonnage—trusses only 12 tons. All connections arc welded in field.

Illinois

Central Illinois—Auditoriums, garage and industrial buildings. Span of trusses 30 ft. to 80 ft. 180 tons. All connections automatic and hand welded. In the years 1926 to 1930, inclusive, Mississippi Valley Structural Steel Co. built approximately the above tonnage of welded trusses of various types. These were used in 38 different buildings.

Commonwealth Edison Co., Chicago—Stack repair. Interior reinforcement of large power stack; vertical angles welded to old plates. Stack about 20 ft. dia. by 150 ft. high.

Mill building, one story, built by C. B. & Q. R.R. at Eola, Ill.

Lord's Dept. Store—Evanston, Ill.—Two stories. New steel added—2 tons. Plates were welded to top and bottom flanges of beams in old building. Arc welded in field. Clamps used in erection.

Donald N. Phillips, Freeport, Ill.—Warehouse for storage of eggs. Width 70 ft. Length 70 ft. Height 14 ft. Span of trusses 67 ft. 4 in. Six tons structural steel. Half section welded trusses with all connections arc welded with exception of splice which was field bolted.

Henry Dubin, Highland Park, Ill.—Private residence. Area 3000 sq. ft. battledeck floors and roof. Tonnage 17. ¾ shop welded, ¼ field welded.

Mississippi Valley Structural Steel Co., Melrose Park, Ill.—Warehouse for structural shapes. Width 133 ft. Length 338 ft. Height 34 ft. 3 aisles. Span of trusses 83 ft. Tonnage 225. Structure includes 10-ton crane runway. Runway girders are of all welded construction, made up of three plates, with bar stiffeners. All this work done by automatic welding machine.

Super Power Co. of Northern Illinois, Powerton, Ill.—Garage extension. Width 63 ft. Length 56 ft. Tonnage—10 tons structural steel added. Height 10 ft. Span of trusses 59 ft. 6 in. Half section welded trusses with all connections arc welded with exception of splice which was field bolted.

Two one-story buildings at Waukegan, Ill. Built by General Boilers Co.; one 25 ft. by 85 ft., the other 25 ft. by 50 ft.

Idaho

Thirteen roof trusses of 50-ft. span; arc welded, 1929, Hecla Mining Co., Wallace, Idaho.

Kansas

Prairie Pipe Line Co., Coney, Kan.—Warehouse. Width 50 ft. Length 120 ft. Height 18 ft. 2 aisles wide. Span of trusses 25 ft. Tonnage 60. All truss connections and splices as well as column splices oxy-acetylene welded. Entire framework fabricated of scrap pipe.

Missouri-Kansas-Texas R.R.—Parsons, Kan.—Railroad reclamation shop. Width 45 ft. Length 90 ft. Height 13 ft. 9 in. Span of trusses 43 ft. 2 in. 110 short tons. All connections oxy-acetylene welded in field. Mill type building with monitor and 3-in. concrete roof. Almost entirely glass inclosed. Window and door frames welded.

Indiana

Inland Steel Co., Indian Harbor, Ind.—Open hearth building. Area 30,000 sq. ft. 33 tons welded battledeck floor. Tonnage does not include columns, exterior walls and roof, all of which contained considerable steel.

Artificial Ice Co., South Bend, Ind.—Storage garage. Width 52 ft. 4 in. Length 130 ft. 4 in. Height 10 ft. 6 in. Span of trusses 52 ft. About 7½ tons of structural steel. Half section welded trusses, with all connections arc welded with exception of splice which was field bolted.

White Swan Laundry, South Bend, Ind.—Trusses for building. Width 37 ft. out to out walls. Span of trusses 36 ft. One ton structural steel. All connections arc welded in shop.

Louisiana

Newellton, La.—Oil storage shed. Dimensions 24 ft. x 36 ft. x 12 ft. All oxy-acetylene welded.

E. M. White Gin Co., Mer Rouge, La., and Oak Ridge Co., Oak Ridge, La.—4-80 cotton gin. Dimensions of high part 24 ft. x 35 ft. x 24 ft. Dimensions of the low part 24 ft. x 44 ft. x 17 ft. All welded.

Planters Gin Co., Rayville, La.—8-80 cotton gin. Steel roof and steel extended wagon shed. Dimensions of building 44 ft. x 79 ft. x 21 ft. Dimensions of shed 44 ft. x 36 ft. x 18 ft. All welded.

Louisiana State University, St. Joseph, La.—Farm implement shed. Dimensions 24 ft. x 72 ft. x 14 ft. All oxy-acetylene welded.

T. B. Gilbert & Co., Wisner, La.—10-80 cotton gin with extended wagon shed. Dimensions of building 44 ft. x 96 ft. x 24 ft. Dimensions of shed 20 ft. x 108 ft. x 14 ft. All welded construction.

T. B. Gilbert & Co., Wisner, La.—Seed storage house. Dimensions 24 ft. x 50 ft. x 18 ft. Completely arc welded. "C" clamps used in erection.

Maine

Office and theater building in Portland, Me., has arc welded steel struts; built 1928 by Lehigh Structural Steel Co. of Allentown, Pa.

Maine Steel Products Co.—S. Portland, Me.—Shop for manufacturing all-welded snow plows. Width 60 ft. Length 200 ft. Height 21 ft. 10 in. One story. Two aisles wide. Span of trusses 44 ft. Tonnage 90.

All field welded, using shelf angles and clamps. All material sent direct from mill to site. All cutting, fitting and welding done on the job. Arc welding.

Maryland

Bethlehem Steel Co., Sparrows Point, Md.—Open hearth floor. Area 80,000 sq. ft. 1450 tons welded battledeck floor.

Massachusetts

Edison Elec. Illuminating Co., Boston—Office. Width 60 ft. Length 115 ft. Height 153 ft. approximately. 14 stories. Tonnage 1230. All field connections arc welded. Shop riveted.

Jacob Shick, Greenfield, Mass. Garage. Width 52 ft. Length 150 ft. Span of trusses 50 ft. Two stories. 116 tons welded battledeck floor. Field welded.

Berkshire Auto Co., Pittsfield, Mass.—Garage. Width 58 ft. Length 140 ft. Two stories. Span of trusses 58 ft. 115 tons welded battledeck floor. Arc field welded.

Shop Building No. 38 at Pittsfield, Mass., plant of General Electric Co. Width 60 ft. Length 270 ft. Three stories in part; one and two stories elsewhere. Fabricated and erected 1928 by American Bridge Co.

Worcester Pressed Steel Co., Worcester, Mass.—Office and museum. Two-third ton welded battledeck floor. Hand field welded. Battledeck floor used for small portion of building.

Michigan

One-story building constructed in Detroit, Mich., for Barnes Wire Fence Co. This structure was entirely field welded; no bolts or rivets were used.

Steel frame of 25-story addition welded to original steel building of First National Bank Building in Detroit, Mich., 1927.

Fifteen-story steel frame addition to J. L. Hudson Co. Department Store, Detroit, Mich. Has steel frame of 12 lower stories welded to existing building of same owner.

Steel frame of 12-story addition welded to original steel building of People's Outfitting Co., Detroit, Mich.

City of Hamtramck, Mich.—High school building. Width 150 ft. Length 220 ft. Height 45 ft. Three stories. Tonnage 280. Seat angles on columns to support floor beams were arc welded. Also to support concrete girders and beams. About 90 per cent of brackets on all columns welded. All miscellaneous steel including walkways, towers, gratings, door frames, etc., shop welded.

Steel frame of four-story addition welded to original steel building of Detroit Trust Co.

Welding employed in some connections for addition to Michigan Bell Telephone Building in Detroit.

Additional floor welded in between original roof and original top floor of Crowley Miller & Co. Department Store, Detroit.

Mississippi

Piney Woods School, Broxton, Miss.—School dining room floor. Half ton welded battledeck floor. Field welded.

Missouri

Building at St. Louis, Mo., plant of Mississippi Valley Structural Steel Co. Dimensions 30 ft. x 50 ft. All shop work welded; field work bolted.

Roof trusses over West Yard at St. Louis, Mo., plant of Mississippi Valley Structural Steel Co. Span 78 ft.

Six-story building of brick and concrete built 1927-1928 by Columbian Steel Tank Co. for their own use in Kansas City, Mo., has a roof of welded tubular construction. Roof is 93 ft. by 120 ft., supported on modified bowstring welded trusses with spans of 42 ft. from center column to each side wall.

St. Louis, Mo.—Machine shop and store room. Width 58 ft. Length 68 ft. Height 34 ft. 1½ stories. Addition to existing building. 15 tons new steel added. All connections arc welded in field.

Stupp Bros. Bridge & Iron Co., St. Louis, Mo.—Office building. 4000 sq. ft. 26 tons welded battledeck floor. Field welded.

Stupp Bros. Bridge & Iron Co., St. Louis, Mo.—Retaining wall. Height 6 ft. 6 in. Length 125 ft. Six tons welded steel. All connections field welded.

Terminal R.R. Assn. of St. Louis, Mo.—Train shed supports. Width 20 ft. Length 3500 ft. Height 14 ft. One aisle wide. Tonnage 600. Cantilever arms for train shed made up by splitting I-beam section, reversing parts, adding wedge-shaped part to base of arm and welding up longitudinal and other joints. All connections hand welded in shop.

Nebraska

American Milling Co., Omaha, Neb.—Hay barn. Width 73 ft. 6 in. Length 190 ft. Height 38 ft. One story. Tonnage 81. Column bases, knee brace and beam connections arc welded to columns, rafter connections welded to columns. All field bolted.

Gate City Iron Works, Omaha, Neb.—Bar warehouse. Dimensions 32 ft. x 105 ft. Clamps used in erection. Arc welded.

Gate City Iron Works, Omaha, Neb.—Structural shop. Dimensions 110 ft. x 160 ft. Center bay 50 x 160 ft. with 10-ton crane; two side bays 30 x 160 ft., with 3-ton crane. Arc welded. Clamps used in erection.

Gate City Iron Works, Omaha, Neb.—Yard crane runway, 500 ft. long by 22 ft. high, 66 ft. span. Capacity 10 tons. Clamps used in erection. Arc welded.

Paxton & Vierling Iron Works, Omaha, Neb.—Ornamental Iron Shop. Width 66 ft. 6 in. Length 92 ft. 4 in. Two stories. Three aisles wide. Tonnage about 87. All connections arc welded.

New Jersey

Atlantic City, N. J.—Power house. Width 74 ft. Length 80 ft. Height 134 ft. Six stories. 551 tons new steel added. Columns arc welded in shop. Connections to columns arc welded in field.

L. Bamberger & Co., now R. H. Macy & Co., Newark, N. J.—Increasing height from 7 to 15 stories. Welding for strengthening columns and field joints. Width 250 ft. Length 250 ft. Height 250 ft. Department store.

Electric Arc Cutting & Welding Co., Newark, N. J.—Addition to factory. Width 200 ft. Length 5000 ft. Type of truss—Heinemeyer.

Prudential Fire Insurance Co., Newark, N. J.—Rebuilding two engine rooms and appurtenances. Dimensions 250 ft. x 250 ft. x 150 ft.

Westinghouse Elec. & Mfg. Co., Newark.—Boiler house. Width 20 ft. Length 40 ft. Three stories. Tonnage 30. All connections arc welded.

Westinghouse Elec. & Mfg. Co., Newark, N. J.—Factory and warehouse. Ground area 70,950 sq. ft. Height 36 ft. Two stories. Span of trusses 59 ft. and 29 ft. Tonnage 1060. All connections arc welded. Erection bolts used.

Wilson Welder & Metals Co., Inc., North Bergen, N. J.—Manufacturing. Width 145 ft. Length 206 ft. Height 12 ft. and 21 ft. Three aisles wide. Tonnage 74. All supports for monorail crane system, also racks, work benches, bins, etc., arc welded. Erection bolts used.

New York

New York Power & Light Corp., Albany.—Service building, contains garage, machine shop, store rooms, repair shops and offices. Width 200 ft. Length 376 ft. Height 36 ft. (3 story) 13 ft.-1st; 12 ft.-2nd; 11 ft.-3rd. Height 13 ft. (garage). ½ is 3 story, i.e. 100 x 376; ½ is 1 story, i.e., 100 x 376. Span of trusses 59 ft. Tonnage 693. All connections were arc welded except purlins resting on trusses of garage portion which were bolted.

Bethlehem Steel Co., Buffalo, N. Y.—Open hearth floor. Area 80,000 sq. ft. 1450 tons battledeck floor welded. Field welded.

Museum of Science of the City of Buffalo, N. Y.—Observatory. Width 12 ft. Length 24 ft. Height 20 ft. One story. New steel added—5 tons. Column splices oxy-acetylene welded in field.

Junior League (swimming pool), New York, N. Y.—Width 2340 sq. ft. 19 tons welded steel.

Kent Garage Investing Corp., New York and Newark.—Auto parking elevators. Width 14 ft. Length 20 ft. Height 17 ft. each. 45 tons. All field connections bolted. Platforms shop arc-welded in single piece. Superstructure bolted. Seven 2-car elevators.

Steel floor at Hershey Chocolate Co., New York City, 24 ft. x 64 ft.

Union Carbide & Carbon Res. Labs., Inc.—Niagara Falls, N. Y.—Metallurgical laboratory. Width 75 ft. Length 260 ft. Height 42 ft. 6 in. One aisle wide. Span of trusses 75 ft. Tonnage 300. All connections oxy-acelylene welded excepting connections on purlins, base, plates, crane rails and miscellaneous bracing. Tiers of mezzanine floor steel one and three stories high within the building were entirely welded, including stairs. Erection bolts used.

Tonawanda Power Co., North Tonawanda, N. Y. Bank and office building. Width 75 ft. Length 171 ft. Height 31 ft. Three stories and basement. Tonnage 209. All connections arc welded.

Fitzgibbon Boiler Co., Oswego, N. Y.—Mezzanine floor boiler shop. Width 22 ft. 6 in. Length 40 ft. 17½ tons welded battledeck floor.

City of Schenectady, N. Y.—City Hall. Width 80 ft. Length 200 ft. Height 56 ft. Three stories and basement. Tonnage 500. All connections arc welded. Erection bolts used.

Mount Pleasant High School, Schenectady.—Roof over auditorium. Span of trusses 76 ft. Tonnage 43. Arc welded in shop.

Y. W. C. A., Schenectady, N. Y.—Club house. Width 230 ft. Length 175 ft. Height 45 ft. Three stories. Span of trusses 36 ft. 205 tons of steel. All connections arc welded. Erection bolts used.

Material shed building. Built 1920 by Electric Welding Co. of America in Brooklyn. Roof trusses 40 ft. span; tested by Department of Buildings, City of New York. Has traveling crane.

Heavy shop building, No. 49, General Electric Co., Schenectady, N. Y., had existing riveted crane runways strengthened and reinforced by welding plate stiffeners to runway plate girder webs, by welding flange angles to web, cover plates to flange angles, and by welding additional flange plates.

Ohio

Peerless Motor Co., Canton, Ohio.—Garage and show room. Width 150 ft. Length 100 ft. Height 30 ft. Two stories and basement. Tonnage 120. All connections arc welded. Erection bolts used.

Prest-O-Lite Co., Cincinnati, Ohio—Main building, P. O. L. Plant. Width 50 ft. Length 80 ft. Height 12 ft. One aisle wide. Span of trusses 50 ft. Tonnage 18. All roof truss connections oxy-acetylene welded.

Prest-O-Lite Co., Cincinnati, Ohio—Charging building, P. O. L. plant. Width 27 ft. Length 158 ft. Height 8 ft. One aisle wide. Span of trusses 27 ft. Tonnage 8. All roof truss connections oxy-acetylene welded.

Prest-O-Lite Co., Cincinnati, Ohio—Storage building, P. O. L. plant. Width 30 ft. Length 60 ft. Height 10 ft. One aisle wide. Span of trusses 30 ft. Tonnage 4. All roof truss connections oxy-acetylene welded. Shop and field welded. Erection bolts used.

A four-story retail store building, 60 ft. x 119 ft., erected by the Austin Company, Cleveland, built 1928. Arc welded. Steel tonnage 115. No rivets or bolts used in the steel frame.

Main factory building of the Lincoln Electric Co., Cleveland, Ohio. Consists of three stories and a basement and has vertical members welded: constructed in 1926. Building is 50 ft. by 130 ft.

Four stories added in 1928 to existing six-story Rose Building, Cleveland, Ohio, and old columns strengthened by arc welding.

Lange Portable Electric Welding Co., Cuyahoga Falls, Ohio—Commercial. Width 60 ft. Length 100 ft. Height 20 ft. Three aisles wide. Span of trusses 30 ft. Tonnage 60. Cut by torch and arc welded. 1/3 shop welded; 2/3 field welded.

Building at Youngstown, Ohio, built 1926 by Youngstown Welding Co. Dimensions, 70 ft. by 220 ft., carries traveling crane. All field erection welded; no bolts or rivets used.

Oklahoma

Black-Sivalls & Bryson, Inc., Oklahoma City.—Fabricating shop for welded and riveted steel vessels. Width 140 ft. Length 260 ft. Height 80 ft. Span 37 ft. 6 in. Height 60 ft., span 25 ft. Two bays wide. Tonnage 250. Erection bolts and arc welded field joints.

Pennsylvania

Lehigh Structural Steel Co., Allentown, Pa.—Enlarge shop. Width 30 ft. Length 120 ft. Height 19 ft. 7 in. One aisle wide. New steel added 37 tons. Arc welded. Purlin clips and end connections on rafter beams, seat angles, for rafter beams; for girts and brackets for crane runway, all on the new columns welded. Erection bolts used.

Westinghouse H. V. Insulator Co., Derry, Pa.—Kiln tunnel building. Dimensions 150 x 460 and 142 x 120. Area 86,000 sq. ft. Height 17 ft. and 24 ft. One story. Five and nine aisles wide. Maximum beam span 52 ft. Tonnage 335. All connections arc welded in field.

Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.—A.C. High Voltage Laboratory. Width 66 ft. Length 159 ft. Height 37 ft. One story. One aisle wide. Span of trusses 65 ft. Tonnage 162. All connections arc welded.

Westinghouse Elec. & Mfg. Co., E. Pittsburgh—Automatic automobile parking machines. Width 50 ft. Length 50 ft. Height 106 ft. Tonnage 208. All

connections arc welded in field. Clamps used with bolts only at column splices.

Westinghouse Elec. & Mfg. Co., E. Pittsburgh—Chemical laboratory. Ground area 3500 sq. ft. Height 46 ft. Two stories. New steel added 35 tons. All connections arc welded.

Westinghouse Elec. & Mfg. Co., E. Pittsburgh—Circuit breaker testing. Width 50 ft. Length 46 ft. Height 35 ft. One story. One aisle wide. Span of trusses 50 ft. Tonnage 60. All connections arc welded in field.

Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.—Direct current testing laboratory. Width 60 ft. Length 100 ft. Height 32 ft. Span of trusses, 60 ft. Tonnage 100. All connections arc welded in field.

Westinghouse Elec. & Mfg. Co., E. Pittsburgh—Dual elevator shaft. Ground area 250 sq. ft. Height 181 ft. 14 stories. New steel added—68. All connections arc welded. Clamps used.

Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.—Engineering Laboratories. Width 120 ft. Length 222 ft. Height 158 ft. 11 stories. Tonnage 1975. All connections arc welded. Erection bolts used.

Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.—Factory. Width 20 ft. Length 42 ft. Height 36 ft. Two stories. New steel added 15 tons. All connections arc welded.

Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.—Garage. Width 63 ft. Length 96 ft. Height 8 ft. One story. One aisle wide. Tonnage 17. All connections arc welded in field.

Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.—Research laboratory. 14,230 sq. ft. ground area. Height 57 ft. Three stories and basement. Tonnage 362. All connections arc welded. Two new wings and boiler house.

Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.—Rolling mill building. Width 80 ft. Length 168 ft. Height 30 ft. One story. One aisle wide. Span of trusses 80 ft. Tonnage 165. All connections arc welded in field.

Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.—Roof sign. Length 260 ft. Height 50 ft. New steel added 52 tons. All connections arc welded.

Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.—Storage of hydrogen and oxygen. Two gas tanks. Diameter 30 ft. Height 28 ft. when full. Tonnage 44 for 2 tanks. All connections arc welded in field.

Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.—Tank shop. Width 106 ft. Length 675 ft. Height 39 ft. One story. Tonnage 450. All connections arc welded in field.

Alpha Portland Cement Co.—Kiln House, Martins Creek, Pa. Width 100 ft. Length 100 ft. Height 40 ft. Three aisles wide. Span of trusses 40 ft. New steel added 4 tons. "C" clamps used in erection. All connections arc welded in field. 10 roof trusses reinforced.

Norristown, Pa.—Extension to Court House. Width 60 ft. Length 201 ft. Height 94 ft. Seven stories. 807 tons new steel added. Column connections arc welded in field.

Westinghouse Elec. & Mfg. Co., North Trafford, Pa.—Factory group. Ground area 93,140 sq. ft. Height 34 ft. in 1-story parts. 1 to 3 stories. Tonnage 1037. All connections arc welded in field. Clamps and erection bolts used.

P. & L. E. Ry., Pittsburgh.—Crane runway about 450 ft. long. Girders about 35 ft. Arc welded in field. These girders were increased in capacity from 7½ tons to 40 tons without cutting or driving a rivet. Clamps used in erection.

D. & H. Ry. Co., Scranton, Pa.—Freight house. Width 34 ft. 8 in. Length 280 ft. 3 in. Height 30 ft. 1 aisle wide. Span of trusses 31 ft. 4 in. Tonnage 46. Trusses, struts and door frames arc welded in shop. The feature of the job was 21 trusses (42 ft. long x 9 ft. high) all alike. Each truss weighed 2000 lb.

Allegheny Country Club, Sewickley, Pa.—Automobile shelter. Width 17 ft. Length 168 ft. Height 9 ft. Tonnage 12. "C" clamps used. Structure is of special design, using welded frames, cantilevered over space used by autos. Roofing carried on angle purlins welded to frames. Arc welded in shop and field.

Westinghouse Elec. & Mfg. Co., Sharon, Pa.—Factory, heavy loading. Width 70 ft. Length 220 ft. Height 80 ft. 5 stories and mezz. 3 aisles wide. 11 pairs of 45 ft. plate girders carry 4-story columns. Tonnage 790. All connections arc welded in shop.

Westinghouse Elec. & Mfg. Co., Sharon, Pa.—Factory, one story. Ground area 4860 sq. ft., 2 aisles wide. Tonnage 27. All connections arc welded in shop.

Sunbury Converting Works, Sunbury, Pa.—New steel added 5 tons. Wedges and "C" clamps used in erection. All connections arc welded in field. Floor reinforced by additional columns and floor beams.

Westinghouse Elec. & Mfg. Co., Trafford City, Pa.—Boiler house. Width 40 ft. Length 56 ft. Height 62½ ft. Tonnage 125. All connections arc welded in field.

Shop Building No. 1, West Philadelphia, Pa., plant of General Electric Co. Approximately 1000 tons of beams, columns and trusses. Electrically welded, 1927-28. Shop 136½ ft. wide by 551 ft. long, with a wing. Trusses 58½ ft., 77 ft. and 78 ft. spans. Has bridge cranes and wall cranes.

Rhode Island

One-story shop, 53 ft. wide by 72 ft. long, erected 1928 in Providence, R. I., by Providence Steel & Iron Co. for its own use. Roof trusses 53 ft. span.

Texas

Dallas, Tex.—Office building. Dimensions 100 ft. x 100 ft. at base. Tower 54 ft. x 96 ft. Height 229 ft. 2 in. 19 stories. Two 51-ft. span, five 62-ft. span. Tonnage 1215. Erection bolts used. All connections arc welded in shop and field.

One-story garage at Dallas, Tex., built by Dallas Power & Light Co. Two units, each 16 ft. x 140 ft.

Three large steel hangars for Houston, Tex., municipal airport. Each hangar's arch steel frame is 75 ft. wide, 125 long, and approximately 50 ft. high. All steel was arc welded in 1928. No bolts or rivets used.

Virginia

New hotel building, 180 ft. high; 60 ft. x 72 ft.; built 1928 for Hotel Homestead, Hot Springs, Va. Eleven full stories in tower portion with smaller floors within sloping roof and cupola. Tower flanked either side by six-story wings, 40 ft. x 47 ft., 560 tons of steel. Arc welded in shop and field.

Newport News Shipbuilding and Dry Dock Co., Newport News, Va. Completely arc welded 10-ton overhead traveling crane installed. Width 54 ft. Length 63 ft. 8 in. Height 24 ft. 7 in. Span of trusses 54 ft. New steel added 45 tons. All connections arc welded in shop. Crane girders supported by 8-in. pipe.

West Virginia

Six-story new addition to Ohio Valley General Hospital, Wheeling, W. Va., erected by R. R. Kitchen Co., 1928, all field connections arc welded; shopwork riveted. Steel tonnage 150.

Wisconsin

Two-story boiler shop at Schueter Boiler Works, Janesville, Wis. Building 66 ft. wide by 86 ft. long. No bolts or rivets used.

A. O. Smith Corp., Milwaukee, Wis.—Research and engineering building. 8 stories. 1237 tons welded battledeck floor. Intermittent electric arc field welded.

Welded trusses in Building for Modern Power Device Co. at Port Washington, Wis.

Cuba

Gas purifier—Havana, Cuba. Width 33 ft. Length 100 ft. Tonnage 205. All connections arc welded in field. Structure equivalent to 3-story building. Tack welds used in erection.

Miscellaneous

Nine steel swimming pools located in 8 cities. Width 20 ft. to 30 ft. Length 60 ft. to 80 ft. All connections arc welded in field. Jobs: Poughkeepsie, N. Y., Y. W. C. A.; Washington, D. C., New Y. W. C. A.;* Cornwall, N. Y., N. Y. Military Academy; New York, Park Central Hotel;* Y. M. C. A. or Y. W. C. A., at Boston, Denver,* Scranton; Greensburg, Pa., High School; New York, Women's Swimming Assn.*

*Means all steel. Others have steel walls and concrete floor.

Building Up Lengthens Life of Lumber Chains

By J. P. WATERS

✦ Mr. Waters is connected with the Linde Air Products Company.

JUST as a chain is no stronger than its weakest link, no link is stronger than its weakest part. Realizing this, and because in bull chains the weakest point of every link is eye, the part adjoining the links rub. A large lumber company on the Pacific coast decided to prevent chain failures and lower link replacement costs by building up the eyes by welding.

These bull chains, made of 2-in. round steel bars, are used for hauling the heavy logs into the mill and are in service 24 hours a day. After two years of such heavy duty, the links wear down ¾ in. at the eye. To replace them with new ones would be extremely expensive, each 14-in. link costing almost five dollars. Instead, this mill makes the links as good as new by using welding to build up the worn surface. This costs less than a dollar, including labor and material charges. Furthermore, after building up, the links are actually

Fig. 1—Building Up Worn Chain by Welding

twice as strong as they were when new, as is demonstrated by the fact that links so built up two years ago show only ⅜ in. wear, whereas new links installed at the same time have worn down ¾ in. Finally, the real advantage of this process is that it makes the life of each link practically unlimited by making it possible to build up the worn section time after time over a period of many years.

Confining the Heat

By DE W. ENDICOTT

✦ Mr. Endicott is connected with the Technical Publicity Dept. of the Linde Air Products Co.

IN the welding of large and intricate castings, it is often necessary to localize the heat in the vicinity of the weld to prevent distortion, and to compensate for expansion by heating part or all of the casting. An ingenious method for confining welding heat to a limited area was recently used in a large Western plant.

The steampipe flange connection on a heavy cylinder block had been broken off completely as may be seen in Fig. 1. It was necessary to weld the flange without disturbing the steamchest, which had been carefully machined and the liner bushing pressed in. Excessive heat from the welding might either distort the steamchest sufficiently to require removal of the liner, reboring the casting and insertion of a new bushing.

The Plant Welder, realizing these possibilities, packed the steamchest liner with well dampened molder's sand and also covered the outside of the steamchest with damp sand, leaving sufficient room for manipulating the welding blowpipe.

When the weld was completed, the casting was allowed

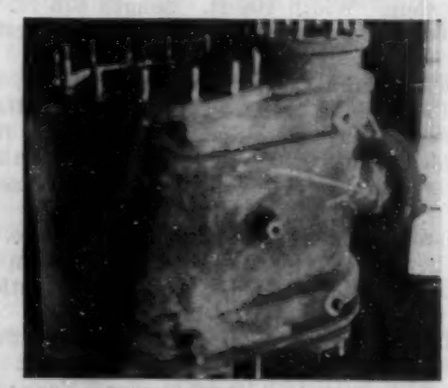


Fig. 1—Flanged Connection on Heavy Cylinder Block Where Weld Was Made

to cool slowly. Careful measurements failed to reveal any appreciable distortion and no machining of casting or steam-chest liner was necessary.

The Welding of Alloys

By **RICHARD TULL**

✦ Mr. Tull is connected with the Union Carbide Co.

IN practically every branch of the metal industry the trend is toward the use of alloy materials wherever possible. In the ferrous field manufacturers have become educated to the knowledge that alloy steels and irons, in spite of their higher initial cost, are in many applications more economical than ordinary iron or steel when their total service life is considered. The advantage may lie in reduced weight; greater strength; greater resistance to abrasion, corrosion, shock, impact or fatigue; or perhaps greater structural beauty may be a deciding factor.

The use of chrome-nickel steels for architectural decoration, kitchen equipment, household fixtures, and for apparatus subjected to corrosion and oxidation is becoming more and more general. Manganese steels are

Fig. 1—Welded Chrome Nickel Steel Airplane Exhaust Manifold

especially well adapted to supply toughness and resistance to shock and abrasion. Vanadium imparts high strength and resiliency to steel. Similar properties in chrome-molybdenum steels have made them practically standard materials for a majority of the structural parts in aircraft. The corrosion-resistant properties of high silicon irons have resulted in their extensive use in acid handling equipment.

In the non-ferrous field, many new alloys are being developed, and their use together with that of the common metals is being rapidly extended. Aluminum and its strong alloys such as Duralumin are being used for furniture, tanks and many kinds of sheet metal work. Copper and copper-bearing alloys find considerable application for parts encountering corrosive agents that would soon destroy ordinary carbon steel. Nickel, Monel metal, brass and bronze, and galvanized iron all have certain uses.

Parallel with this advance in the types of construction material, the method of joining metals has changed in favor of welding wherever possible. Refinements in the process and the application of procedure control have brought welding to the point where it has become an economic factor in the manufacture of metal products. It is therefore both interesting and important to realize that practically all types of alloys can readily be welded by the oxy-acetylene process. Naturally, the procedure used in the welding of iron and steel cannot be transferred in its entirety. Most alloys have qualities peculiar to themselves, which require slight alterations from the standard practice.

Chromium and Chrome-Nickel Steels

The alloying of chromium and nickel with steel develops properties which must be thoroughly understood before any attempt is made to weld the metal. However, certain definite procedures must be followed in every case.

A neutral flame should always be used where strength and ductility of the weld are important. An excess acetylene flame increases the carbon content of the weld metal and reduces ductility and resistance to corrosion. An excess oxygen flame leads to excessive amounts of infusible oxides which cause porous welds. The flame should be just large enough to insure proper fusion because too much heat may cause boiling of the metal with subsequent porosity. The welding rod should be of the same composition as the base metal; otherwise the physical and chemical properties of the metal adjacent to the weld may be altered. The use of a proper flux is of the utmost importance for it prevents excessive atmospheric oxidation or carburization by the flame. It must readily dissolve iron and chromium oxides and produce a slag of the proper consistency and fusibility at the welding temperature of these alloys. A flux such as Cromaloy, prepared especially for chromium alloys should be used.

The foregoing precautions and procedures are applicable to practically any of the high-chromium alloys. However, in every case, the properties of the particular metal should be understood before any welding is attempted. The percentages of carbon, chromium, and nickel present in the steel have varying effects on the weldability of the material. For convenience the high-chrome alloys may be divided into three general groups: Stainless steels and irons, containing

Fig. 2—Welded Aluminum Milk Cans

12-17 per cent chromium; austenitic steels such as 18-8, containing 17-25 per cent chromium and 7-12 per cent nickel; and high chromium alloys containing up to about 30 per cent chromium.

Stainless Steels and Irons—Stainless steel, which has a carbon content of over 0.20 per cent, must, because of its air-hardening qualities, be annealed and slowly cooled after welding in order to remedy the hardness and brittleness of the welding and adjacent metal. This, however, partially reduces the corrosion resistant qualities of the metal, so that welding is inadvisable where the utmost strength and resistance to corrosion are required. Stainless iron, with less than 0.12 per cent carbon, can readily be brought back to its original condition by annealing and slow cooling. With the proper care, the welding blow-pipe can be used for the heat treatment.

Austenitic Steels—The austenitic types of alloy are not subject to the brittleness encountered in the first group, and do not require subsequent heat-treatment. A flux is not absolutely necessary to the welding procedure, but its use is recommended for the best results. High-chromium, high-nickel alloys containing 7-25 per cent chromium and 17-22 per cent nickel have properties similar to the better known lower alloy austenitic steels and are readily welded.

High Chromium Steels—The high-chromium alloys, because of their high chromium content, are somewhat more difficult to weld because of the tendency toward the formation of an infusible oxide or slag. The welds will be strong, but brittle up to a good black heat. However, the operating temperatures of this type of material are apt to be high enough to be within this range, so that in actual practice the brittleness at low temperatures may not greatly affect the part.

Low Chromium Steels—The alloy steels containing low percentages of chromium such as the 1.00 per cent chromium steels are readily welded by the usual methods employed for chromium steels. As in the case of the high-chrome alloys, the strength and ductility of the weld and adjacent base metal is greatly improved by subsequent heat-treatment.

Fig. 3—Welding an Aluminum Tank

Chrome-Manganese Steel—A fairly recent innovation in the chrome steel field is the use of manganese to form an 18-8 chrome-manganese steel. Manganese in a percentage of about 8 per cent imparts very desirable physical properties to the alloy. It can be welded readily with either a higher manganese steel welding rod developed for high carbon steel or with chrome-molybdenum steel welding rod. It is welded in a manner similar to that used for 18-8 chromium-nickel steel, but it welds more easily than the well known chrome-nickel alloy. With the use of the proper flux and a neutral flame, very strong, ductile welds may be obtained. Once again it should be emphasized that the use of a neutral flame is most important in welding high-chromium steels. Some welders favor an excess acetylene flame because the metal flows better. However, the carbon content of the material is raised, and this reduces the ability of the steel to resist corrosion.

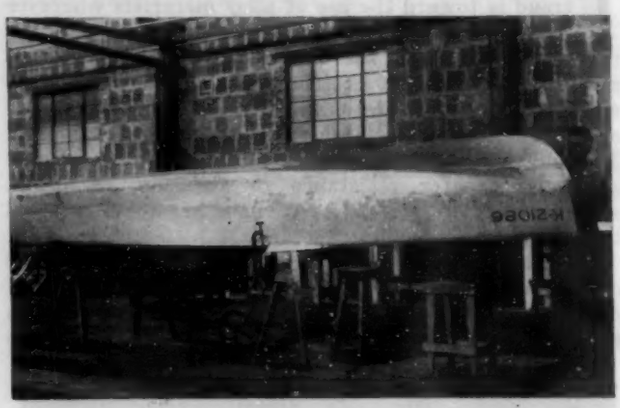


Fig. 4—Duralumin Hull, Welded

In many cases the safest practice is to check with the alloy manufacturer or with the oxygen supplier.

Manganese Steels

For discussion the manganese steels may be roughly divided into two groups: high manganese and Hadfield steel. High manganese contains from 1 to 2 per cent manganese, while Hadfield has a manganese content of from 12-14 per cent. Use of the ordinary welding procedure with a manganese-tungsten welding rod will give excellent results on high manganese steel, as will manganese-molybdenum and nickel-vanadium rods. Subsequent annealing seems to have little effect on the strength and ductility of the welds and adjacent metal.

In the welding of Hadfield steel, a manganese steel rod of the same composition as the base metal must be used. The use of a flame having a slight excess of acetylene will assist somewhat in making a sound weld. A large flame should be used and a large pool of melted metal maintained. The rod should not be rubbed in the weld; but it should be left in the pool and melted under the surface of the liquid metal. When the pool is built up sufficiently, it should be melted into the base metal by applying heat around the edges until the weld and base metal flow together of their own accord. The material should be pre-heated and reheated in a manner similar to the usual practice for cast iron. Because of the brittleness of red-hot manganese steel, care should be taken to support heavy pieces against strain during welding.

Fig. 5—Welding Chrome-Molybdenum Tubing

Molybdenum, Vanadium, and Silicon-Manganese-Chromium Steels

The purpose of using any of these three types of alloy steel is mainly for developing maximum strength with good ductility, resistance to shock and greater resiliency. As is usual with nearly all welded joints, heat treatment of the welds will produce better physical properties. This normalizing may be done either in a furnace or by means of the welding blowpipe. The furnace treatment is advisable where it is possible to obtain it, but in many cases the location of the weld is such as to preclude such practice. Under such circumstances very satisfactory results may be obtained with the blowpipe treatment. The welds should be allowed to cool to a black heat and then be taken up through the critical range of 1400-1500 deg. F. Care must be taken to prevent heating above this range because coarse grained structure is apt to occur. After being held at this temperature for a few minutes, the material should be allowed to cool in air, provided the piece is not too thick or too thin. The cooling in air of a thin sheet would be equivalent to quenching a thicker section, while air cooling a large block would be too slow. Therefore, the rate of cooling should be considered for the best results. In some cases it may be necessary to temper the steel after normalizing.

Silicon Irons

Probably the only type of silicon iron requiring particular mention is that containing from 12-14 per cent silicon, such as Duriron. If the proper technique is rigidly adhered to, it is possible to make a joint as strong and as corrosion resistant as the parent metal. Duriron rod should be used and fluxed with a mixture of equal parts of borax and sodium bisulphate.

In repairing a hole, the metal around the opening should be melted away until clean metal is reached. The hole should be backed up with molding sand and the spot filled with material from the rod. When welding is done on a flat surface, a molding sand backing must be used. The edges of the metal should be melted down to form the weld at the bottom of the vee. The weld should then be built up with rod.

Casting cracks are hard to repair because of the tendency of the crack to open up either during welding or cooling. Cutting or drilling a small hole an inch or so in front of the break may sometimes prevent further fracture. The casting should be preheated to about 1100 deg. F. (cherry red), the previously veed edges of the crack melted down, and the joint built up with rod. The pieces should then be allowed to cool over a dying fire. Molten Duriron is very fluid, so the welding process must be more rapid than for cast iron. A neutral flame should always be used, and the rod kept under the heavy coating of slag that is formed on the melted pool.

Aluminum and Its Alloys

Among the non-ferrous metals and alloys, aluminum probably ranks first in its scope of applications. Every day some new use is developed which takes advantage of its strength or light weight. Everything from kitchen ware to furniture to airplane parts is included in its field. The welding of aluminum requires a somewhat different technique than that for steel, but any welder can, with a little practice, easily produce good, sound welds. Since the coefficient of expansion of aluminum is about twice that of iron, care must be taken to minimize warping and buckling by the suitable location of welded joints and through the use of jigs and backing. A good aluminum flux must be used in order to remove the oxide coating on the metal.

When aluminum alloys are welded, care must be taken to avoid contraction strains because many of the

Fig. 6—Assembling Aircraft Members

alloys are extremely hot short. Pre-heating or assembling the material so that the metal adjacent to the weld can readily contract will aid in properly joining the pieces.

A low melting point alloy aluminum rod is very well adapted to general welding work. It does not harden as readily as does the adjacent metal and so is able to take up considerable of the stress ordinarily transmitted to the base material. It also tends to fill up any voids left by the base metal on cooling. If the metal being welded is to be subsequently heat-treated, it is advisable to use a rod of the same composition or to use strips cut from the base metal.

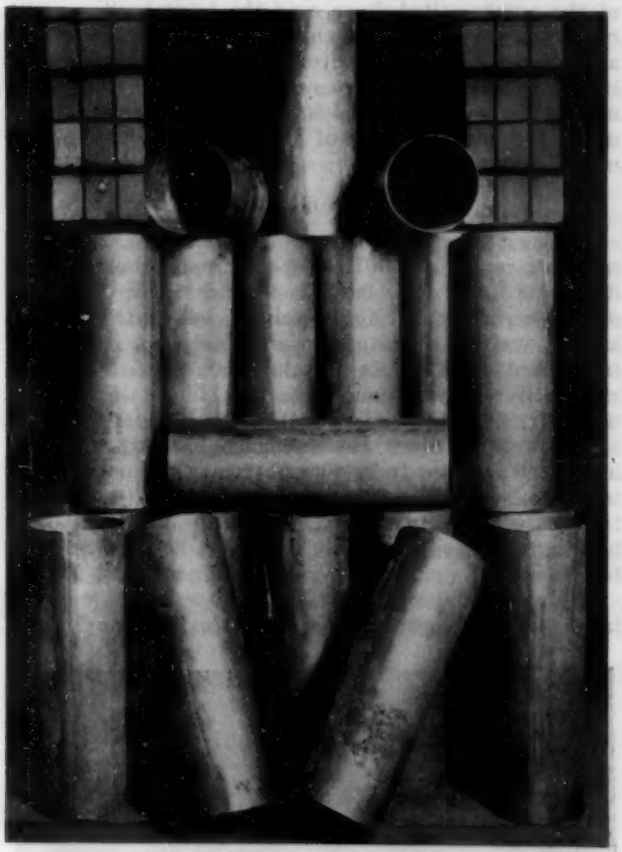


Fig. 7—Cylinders Welded From Everdur

With practically all of the aluminum alloys, heat-treatment after welding is necessary in order to develop the full strength of the joint. For best results the entire part should be heat-treated in a furnace. The proper procedure consists in heating to a temperature of 890 to 940 deg. F. and quenching in cold water or oil. Depending upon the size of the article, the time of heating should be from 15 min. to 1 hr. Welds upon which no heat-treatment is to be made should be painted with spar varnish.

Nickel and Monel Metal

The use of sheet nickel and of Monel metal in dairy and chemical equipment has led to many inquiries as to the weldability of these materials. The welding procedure in both cases is practically identical, so that a discussion of the process of joining pure nickel sheets may be taken as correct practice for Monel metal. The procedure differs but slightly from that of steel, and if these variations are followed, no trouble will be encountered during welding.

Extreme care must be taken to prevent oxidation of the molten nickel. The welding flame, while kept neutral, should be slightly on the reducing side, because any excess of oxygen will cause poor welds. The welding head should be one size larger than that specified for steel of the same thickness. Welds should be completed in one operation with the blow-pipe kept on the work so that the envelope of flame will protect the metal from oxidation. The black oxide forms on top of the weld, so that if an attempt is made to build up the weld in layers the oxide on the surface of the first layer will be melted into the succeeding layer and will produce gas holes. By building up the weld well above the surface, it is possible to grind off the dross and so insure sound metal throughout the section. All slag and impurities should be brought to the top and floated out. Puddling with the rod will stir in the impurities and should be avoided. Jigs or clamps which will hold the work rigid until it has cooled below a red heat will produce more satisfactory results. On sheet metal up to 1/16 in. thick, flange welds give the best results. The seam should be painted with Brazo flux before welding.

Copper and Its Alloys

Copper—The welding of copper at first presented difficulties which bid fair to retard the growth of the process in the fields in which this metal is used. However, investigation showed the low strength and ductility of welded commercially pure copper to be caused by the presence of minute particles of cuprous oxide which were segregated by the welding temperature in zones adjacent to the weld. It was found that by using completely deoxidized metal and welding rod approximately 70 per cent more strength and three times as much ductility was obtained.

With deoxidized copper and welding rod the welding technique is very similar to that employed for steel. However, the welding head should be one or two sizes larger than for a similar thickness of steel because of the high heat conductivity of copper. Where possible it is best to cover the work with asbestos paper in order to reduce heat losses to a minimum. Large sections, and small parts, if it is practicable, should always be preheated to a dull red. No flux is necessary with pure copper. Since the melting point of copper is lower than that of steel, the blow-pipe must be handled more rapidly than is possible with steel of similar thickness.

A satisfactory method of repairing copper apparatus, and in many cases in the manufacture of such equipment, is bronze-welding. This procedure is especially well adapted to copper which may contain impurities that would result in weak copper welds. The bronze weld adheres to the surface of the material with a bond as strong as the base metal. In repairing a break, the parts are locally heated with the blowpipe flame, bronze welding rod and Brazo flux are applied, and the weld is built up. The joint should be finished by cleaning with a wire brush.

Everdur—This high strength copper alloy contains small amounts of manganese, silicon, and iron, so a rod of the same material should be used for welding. The precedure follows very closely that of welding ordinary copper, except that a mixture of equal parts of Cromaloy and Brazo flux should be used in order to keep down the formation of slag.

Brasses and Bronzes—The composition of these classes of copper alloys is so varied that no general welding rules can be stated. Varying percentages of zinc or tin in the composition cause the materials to

act differently when it is welded. Since in many cases the metal is weak when hot, it is advisable to preheat all brass and bronze pieces, handle them carefully while hot, reheat them after welding, and cool them very slowly. It is not necessary to use a larger welding head than for steel because the relatively low melting point of the alloys offsets the higher heat conductivity. Standard brass and bronze welding rods can usually be used, although in instances where it is necessary to match color, etc., strips of the same material should be used. Brazo flux should be employed, but care should be taken to be sure that no more is used than is necessary, or porous welds may result. The welding should be done in a well-ventilated room in order to obviate as far as possible the danger of inhaling the oxide fumes are likely to produce nausea.

Lead, if present in any appreciable amount, makes welding difficult and causes weak joints. In order to overcome this difficulty, an oxidizing flame should be used on brasses and bronzes having a high lead or high zinc content. The flame adjustment is of the utmost importance in this type of welding. The flame first should be adjusted to neutral, and then the acetylene supply reduced to form the oxidizing flame. It should be noticed that as the amount of acetylene is diminished the flame at first shortens and then gradually lengthens and loses considerable of its luminosity. This last condition is the one necessary for successful welding of these alloys. When such a flame is used a dense coating of slag is formed on the metal, and melting takes place beneath the coating. No boiling or fuming occurs during welding. Although flux is not absolutely necessary, Cromaloy or Brazo flux aids greatly in producing sound welds.

Impact Load Tests on Arc Welded and Riveted Beams

By **E. O. PATON** *and* **A. V. DIATLOV**

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Object of Tests

At the beginning of the present year a series of tests were performed under the direction of the Kieff Experimental Bureau, to determine the strength of arc welded and riveted beams under static loads. To complete these investigations, it is essential to study the behavior of arc welded beams under dynamic loads. In this respect the most significant results are obtained by means of vibration tests. Because a vibration machine was not available, we limited ourselves to impacts by means of a heavy hammer.

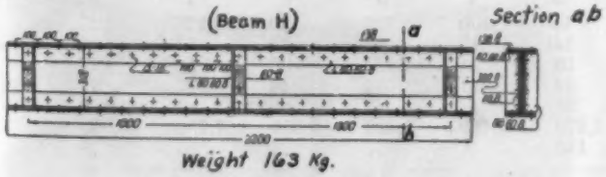


Fig. 1.

These tests were performed on samples which were in all respects identical with those used for static load tests (with the exception of beam L_4, in which the thickness of horizontal plates was 14 mm. instead of 12), so that direct comparison could be obtained, and the effect of suddenly applied loads determined.

Moreover, it is possible to compare the resistance of various designs to sudden impacts.

Description of Samples

According to their designs, the samples tested can be divided into three groups:

1—I-beams without joints. To this group belong the arc welded beams I_3 and L_3, and riveted beam H_3.

Beams H_3 and I_3 (Figs. 1 and 2) have equal moments of resistance.

2—I-beams with a joint. To this group belong the arc welded beam O_3 and riveted beam M_3. Although the moments of resistance of these beams are equal, only 60 per cent of the number of rivets required by computations were put into the joint of M_3.

3—Combinations of longitudinal and transverse beams. To this belong the welded sample W_3 and the riveted beam S_3. The moments of resistance of the longitudinal sections are nearly equal for both samples.

During the tests, sample W_3 was held in a way such that the reinforcement was at the bottom and was subjected to tension. Sample S_3 has no reinforcement. Therefore samples W_3 and S_3 cannot be said to possess equal strength, and the results of tests cannot be compared.

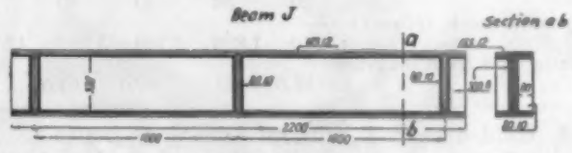


Fig. 2.

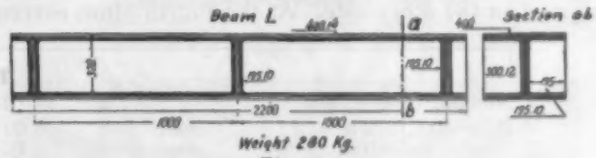


Fig. 3

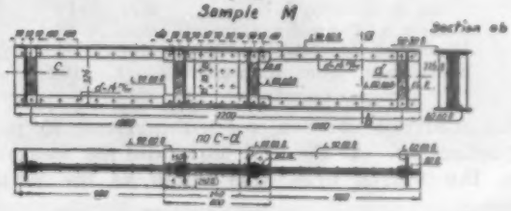


Fig. 4

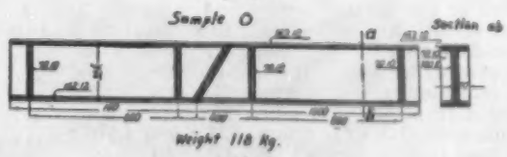


Fig. 5

For every sample, it is possible to compare its behavior under static and dynamic loads.

Description of Tests

The tests on the seven samples described were made by means of successive blows with a heavy hammer. After every blow, deflection measurements were taken and the beam carefully looked over.

Results of Tests

1. Riveted beam H_1 without joint. (Fig. 8.)

The failure of the beam started at the third blow.

Table 1

Number of the blow	1	2	3	4
Height of fall of the hammer, cm.	10	20	30	40
Elastic deflection, mm.	8	7.0	3.0	3.0
Permanent deflection, mm.	5	7.5	13.5	22
Total deflection, f, mm.	13	14.5	16.5	25.0
Deflection obtained from diagram, mm.	11	20	27	35
Dynamic work of the hammer Q(h+f), t. mm.	486	922	1,365	1,825
Static load from diagram, t.	52.0	54.0	57.0	59.0

2. Welded beam I without joint. (Fig. 9.)

At the third blow from a height of 60 cm., the first crack occurred in the horizontal weld. This was taken as the point of failure.

Table 2

Number of the blow		1	2	3	4	5
Height of fall, h	cm.	20	40	60	75	100
Elastic deflection	mm.	15	8	12	7	...
Permanent deflection	mm.	6	17	25	33	66
Total deflection, f.	mm.	21	25	37	40	64
Deflection from diagram	mm.	20	34	49	59	...
Dynamic work, Q(h+f)	t. mm.	910	1,826	2,740	3,390	4,570
Static load from diagram	t.	58.5	61.5	64.0	67.0	...

3. Welded beam L_2 without joint. (Fig. 10.)

The first crack occurred at the second blow, in the horizontal weld. At the third blow, the same crack started on the other side. At the fourth blow, several cracks occurred, with a sudden increase in permanent deflection. As the first blows did not weaken the beam, the fourth blow was taken as the point of failure.

Table 4

Number of the blow		1	2	3	4	5
Height of fall, h	cm.	10.8	20.2	31.5	40.0	50.0
Elastic deflection	mm.	7	8	6	...	...
Permanent deflection	mm.	6	20	30	...	...
Total deflection, f.	mm.	13	28	36	...	...
Deflection from diagram	mm.	14	23	34	...	...
Dynamic work Q(h+f)	t. mm.	521	980	1,510	...	...
Static load from diagram	t.	47	50	48	...	...

4. Riveted beam M_2 with joint. (Fig. 11.) Table 4. The vertical rivets sheared at the second blow. The horizontal rivets sheared at the third and fourth blows.

5. Welded beam O_2 with joint. (Fig. 12.)

Table 5

Number of the blow		1	2
Height of fall, h	cm.	20	10
Elastic deflection	mm.	..	..
Permanent deflection	mm.	66	..
Total deflection, f.	mm.	62	..
Deflection from diagram	mm.	23	..
Dynamic work, Q(h+f)	t. mm.	1,128	..
Static load from diagram	t	60	..

Failure started at the first blow, from a height of 20 cm. the crack occurred in the transversal weld. The second blow, from a height of 10 cm., produced full failure.

Table 6

Number of the blow		1	2	3	4
Height of fall, h.	cm.	10	20	30	10
Elastic deflection	mm.	18	..	..	..
Permanent deflection	mm.	22	..	..	..
Total deflection, f.	mm.	40	70	..	..
Deflection from diagram	mm.	38	58	..	..
Dynamic work, Q(h+f)	t. mm.	602	1,161	1,290	..
Static load from diagram	t	24	29	30	..

Riveted sample S_2. (Fig. 13.)

The first blow resulted in a noticeable motion of the rivets. The second blow, from a height of 20 cm., the lower rivets sheared.

Table 7

Number of the blow		1	2	3	4
Height of fall, h.	cm.	10	20	30	10
Elastic deflection	mm.	4	3	6	..
Permanent deflection	mm.	5	9	18	..
Total deflection, f.	mm.	9	12	24	..
Deflection from diagram	mm.	12	21	30	..
Dynamic work, Q(h+f)	t. mm.	468	912	1,392	..
Static load from diagram	t	49	53	55	..

7. Welded beam W_2. (Fig. 14.)

At the third blow, the metal in the lower horizontal part cracked, near the transversal weld. The next blow produced complete failure by breaking the vertical part.

Table 3

Number of the blow		1	2	3	4	5	6	7	8
Height of fall, h	cm.	30	50	75	100	125	150	175	225
Elastic deflection	mm.	10	16	24	17	11	14	11	25
Permanent deflection	mm.	7	7	10	24	23	32	42	42
Total deflection, f.	mm.	17	23	34	41	34	46	53	67
Deflection from diagram	mm.	16	25	35	..	..	..	..	..
Dynamic work, Q(h+f)	t. mm.	1,365	2,250	3,370	4,480	5,520	6,650	7,750	10,000
Static load from diagram	t.	102	107	110	..	..	..	..	..

Comparison of the Strength of Welded and Riveted Beams

The basis we have been using in our computations is the work Q(h + f) done by the hammer during its fall, where Q is the weight of the hammer, h the height of fall, and f the deflection of the beam. This quantity of work, used up in producing deformations in the sample, changes with the resistance offered by the beam, and is therefore a measure of its strength. The values of this quantity in ton-millimeters, for

each impact, have been computed in Tables 1 to 7. The problem is to determine how to use these values so as to get a measure of the strength, or "fitness for work" of the samples tested. Blount and Kirkaldy propose that the resistance to impacts be determined from the work necessary to produce a unit permanent deflection in the sample. Guillet considers the ratio

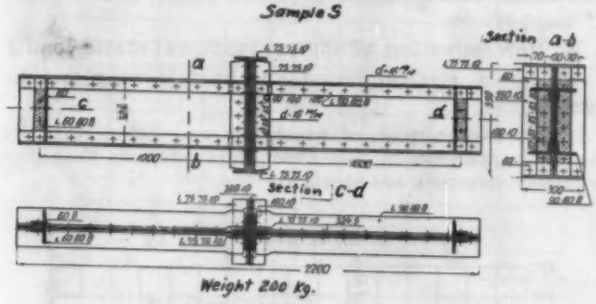


Fig. 6.

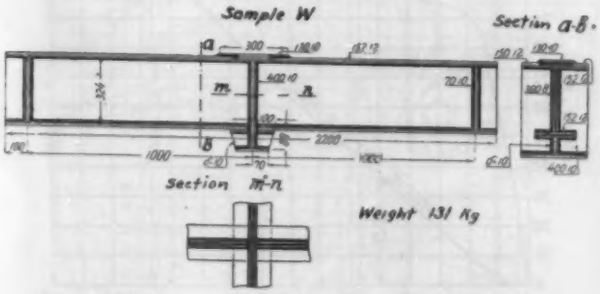


Fig. 7

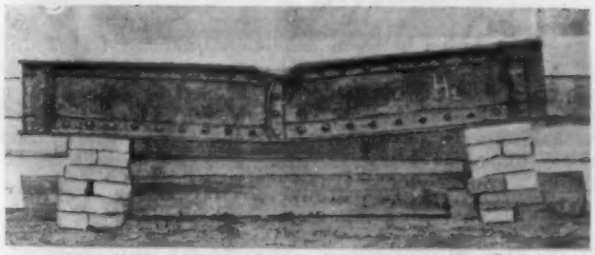


Fig. 8

Fig. 9

of the work done in breaking the sample in a Charpy machine to the cross-sectional area of the sample, and finds that it gives a satisfactory idea of the strength of steels with different carbon contents. According to Moser, it is possible to take the ratio of the work to the work area determined from the diagram of flow. Finally Schimpke and Horn judge the resistance of round bars from the work and angle of twist at failure.

In these tests, we shall use the ratio of the work used up in destroying the beam to the cross-sectional area of the latter, and also the ratio of this work to the moment of inertia. Both ratios are characteristic of the strength of the beam.

The work necessary to destroy the beam will be taken as the sum of all values of work used up from the first impact to the last, inclusively. The measure of the work used up at static loading will be taken as the area of the Static Diagram (Sec. 6), measured up to the point where the value of the force starts to decrease. Comparing these two values of work for welded beams in Table 8, we find that, excepting sample O, the impact work is two to three times larger

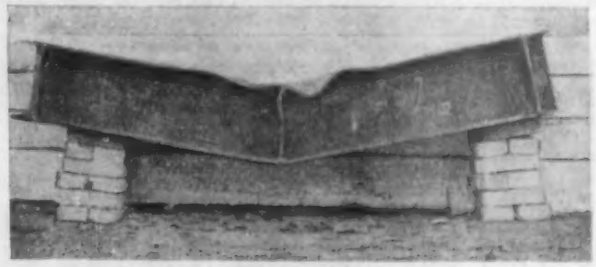


Fig. 10

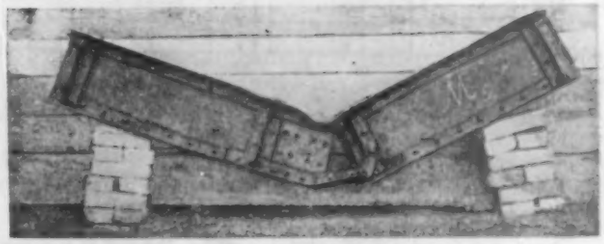


Fig. 11

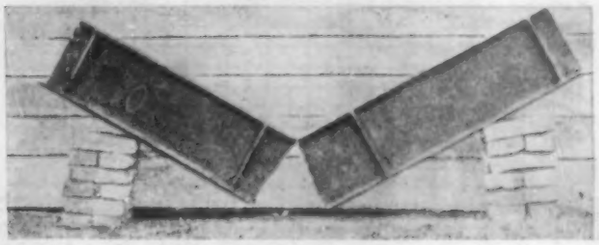


Fig. 12

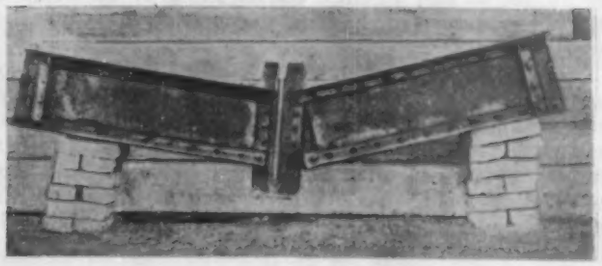


Fig. 13

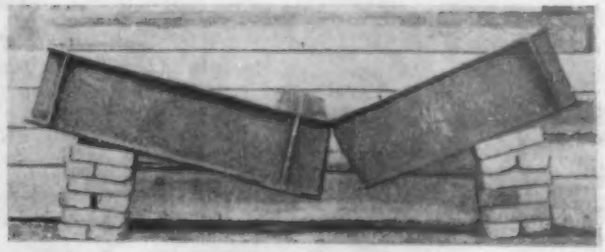


Fig. 14

than the static work. From this we cannot, however, conclude that the resistance of welded beams is two to three times larger to impact loads, for the following reasons: The static work has a definite value, depending upon load and deflection, whereas the dynamic work has a single value only in the case where it is produced by a single impact of the hammer. When the dynamic load is taken as the sum of several values of work, produced by several impacts, the value obtained depends upon the number and intensity of the blows. Therefore the values, in Table 8, representing static and dynamic work, cannot be compared.

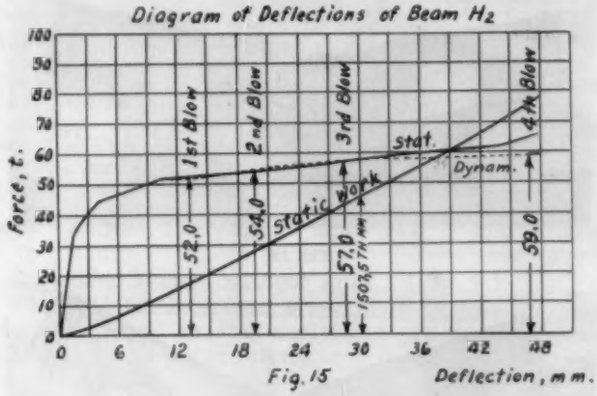


Fig. 15

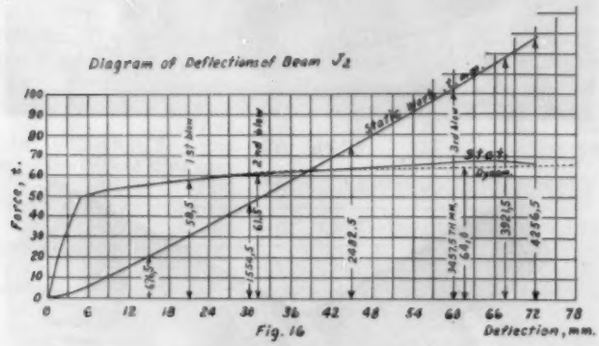


Fig. 16

Values of dynamic work in Table 8 are perfectly comparable among themselves, since they result from identical blows on all samples from identical heights of 10, 20, 30 and 40 cm. The strength of the beam is thus characterized by these consecutive values of work.

Comparing the dynamic work ratios on Table 8, we see that welded beams offer better resistance to dynamic loads than riveted beams, with exception of beam O, which broke at the first impact from a height of 20 cm. This abnormal behavior was due to a poor weld. To compare each beam as to its strength under static and dynamic loading, we shall use the methods described below.

Comparison of the Strength of Beams at Static and Dynamic Loads

As a basis for this comparison, we can use the value of the load P which gives the same amount of work with static application as by impact. This load P is conventional, as dynamic conditions introduce many additional elements. H gives, however, a good basis of comparison.

A. Determination of the conventional static load P.

We use a method based on the following two assumptions:

1—The two samples, of which one was tested statically, the other dynamically, are exact duplicates, so that their deflection diagrams are identical.

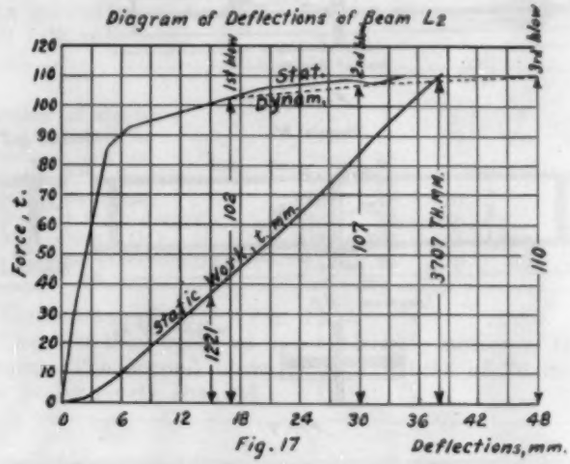


Fig. 17

2—The relation between deflections and the forces producing them depends only upon internal properties of the materials, and not upon the way the load is applied, i.e., statically, or by impact. The work Q(h+f) accomplished by the falling hammer is compared with the work of the fictitious load P acting statically and producing a deflection f:

$$Q(h+f) = \frac{Pf}{2} \qquad (1)$$

on the deflection diagram (Fig. 15-21) the work $\frac{Pf}{2}$ is equal to the area of the triangle. Since P and f are pro-

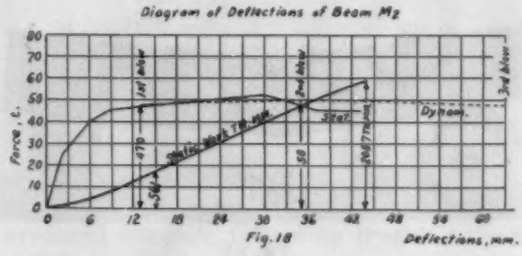


Fig. 18

Table 8

Sample	Cross-Sectional Area, cm²	Moment of Inertia, cm⁴	Total Work to Destruction Static ton-mm.	Total Work to Destruction Dynam. ton-mm.	Ratio of Work to the Area of Cross Section Static ton-mm.	Ratio of Work to the Area of Cross Section Dynam. ton-mm.	Ratio of Work to the Moment of Inertia Static ton-10² cm²	Ratio of Work to the Moment of Inertia Dynam. ton-10² cm²
Weld I	63.6	11,442	3,921.5	5,516	6.16	8.67	3.43	4.82
Riv H	70.76	11,300	2,603.5	2,773	3.72	3.92	2.33	2.45
Weld L	148.0	32,324	3,707	11,465	2.51	7.73	1.15	3.55
Riv M	68.82	10,700	3,420	2,520	4.96	3.66	3.2	2.36
Weld O	60.50	10,700	2,956	1,128	4.88	1.87	2.76	1.05
Riv S	61.36	10,900	1,897	1,763	3.09	2.87	1.74	1.62
Weld W	60.50	10,700	1,459.5	2,772	2.41	4.58	1.36	2.59

portional quantities, this work equals also the area under the curve:

$$Q(h+f) = \int_0^f Pdf \qquad (2)$$

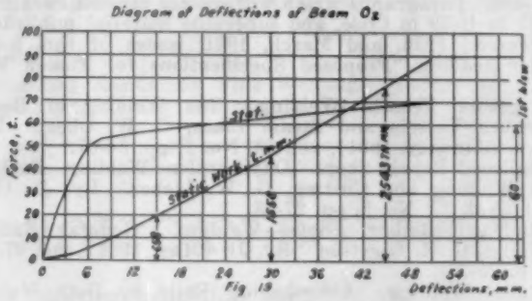
the abscissa of the last point of integration represents a deflection which, as we shall see later, differs little from the deflection measured after the first blow. This is a justification for our assumptions. According to our second assumption, successive impacts are equivalent to successive applications of static loads. Therefore, if for the first blow the integration is carried along the static diagram for the first load, for the second blow the integration must be along the static diagram for the second load, and so on.

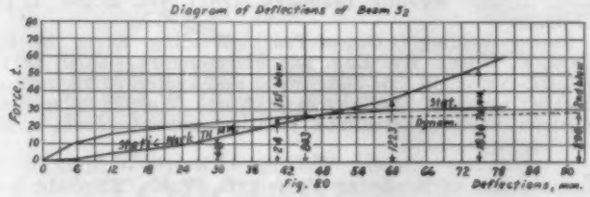
The values of P were determined as folows: On the diagram of deflections, obtained during static tests, we draw the curve of static work. Its ordinates are ton-mm., and represent the work done by the load in producing a deflection equal to the static deflection. To draw this curve, the static diagram is divided into a triangle, and a series of trapezoids, the areas of which are plotted as ordinates.

Having computed the work done by the hammer $Q(h+f)$, we find the one ordinate on the curve of work which is equal to the work of the first blow.

Having found this ordinate, we read on its bottom the deflection, and the point of intersection of this ordinate with the curve of static deflections gives us the load P. The value of P is plotted against the total deflection caused by the dynamic blow, and thus the first point of the dynamic diagram is obtained. In the same way, other points are determined. On Figs. 15-21, these points are joined by dotted lines.

The results are as shown in Table 9.





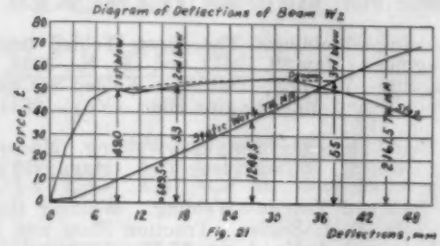


Table 9

Beams	I_2	H_2	L_2	M_2	W_2	S_2
Measured deflection after the first blow, mm.	21	13	17	13	9	40
Deflection obtained from the diagrams, mm.	20	11	16	14	12	38

B. Comparison of dynamic and static loading.

The conventional loads P, thus determined for each blow, are tabulated in Tables 1 to 7. In table 10, a direct comparison is obtained.

From table 10 we see that dynamic and static loads producing failure are nearly equal, from which we can conclude that welded beams offer as good resistance to dynamic as to static loading conditions.

Moreover, comparing the loads P for samples I and H, we see that with equal moments of inertia the welded beam I is stronger than the riveted beam H in the ratio 68:65.9 = 1.03 under static loading, and 64:57 = 1.12 under dynamic loading.

Table 10

Sample	H riv	I weld	L weld	M riv	O weld	S riv	W weld
Static load at failure, tons	65.9	68	110	86.4	69.8	31.2	55.3
Dynamic load at failure, tons	57.0	64	110	83.6	60.0	29.0	55.0

Conclusions

We reach the following two conclusions, both in favor of arc welding:

1—Welded beams offer no less resistance to dynamic than to static loading.

2—Welded beams offer more resistance to dynamic loads than riveted beams.

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